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SILAGE MANUAL

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TABLE OF CONTENTS

	Page		Page
Authors	iii	Nutrient additives	20
Acknowledgements	iv	Cereal grains	20
Introduction	1	Liquid whey	20
Advantages of silage compared to hay	1	Urea	20
Disadvantages of silage	1	Ammonia	20
Silage relative to other production	1	Mineral additives	20
Crops for Silage	2	Silage Harvesting	21
Annual crops for silage	2	Direct cut silage	21
Cereal silage	3	Wilted silage	21
Barley	3	Low moisture silage	21
Oats	5	Harvesting systems	21
Triticale	5	Crop maturity	21
Spring wheat	6	Moisture content	22
Winter wheat	6	Windrowers	22
Spring rye	6	Harvesters	22
Fall rye	6	Wagons and trucks	24
Field peas	6	Harvesting system losses and efficiency	24
Fababeans	8	Silos	25
Silage corn	9	Silage making and storage	25
Sunflowers	11	Forage losses	25
Sorghum-sudangrass	12	Horizontal silos	25
Perennial grasses	12	Filling and packing horizontal silos	28
Perennial and biennial legumes	12	Covering horizontal silos	29
Alfalfa	12	Size and capacity of horizontal silos	29
Sweet-clover	12	Large round bale silage	30
Red clover	13	Storage methods for large round bales	30
Miscellaneous silage crops	13	Tower silos	31
The Ensiling Process	14	Foundation footings for tower silos	31
Factors affecting silage fermentation	14	Pre-cast concrete stave silos	31
Water soluble carbohydrates	14	Cast-in-place concrete silos	31
Buffering capacity	15	Concrete tower silo preservation and repair	31
Moisture content	15	Oxygen limiting silos	32
Type of bacteria which predominate	15	Filling a tower silo	32
Speed of fermentation	15	Sizing and tower silo capacity	32
Characteristics of good ensiling procedures	16	Bagged silage	33
Exclusion of air	16	Silage bags (continuous tubes)	33
Low temperature	16	Bag capacity and location	34
Rapid acidification	16	Feeding silage	34
Methods of controlling the ensiling process	16	Safety in silage making and storage	34
Moisture content	16	Evaluating Silage Quality	36
Mechanical pretreatment	17	Quality of the forage	36
Rapid filling, packing and sealing	17	Obtaining samples for quality examination	36
Use of additives	17	Visual evaluation of silage	36
Opening the silo	17	Chemical analyses of silages	36
Silage Additives	18	Silage pH as an indicator of quality	36
Specific silage additives and preservatives	18	Fermentation products in silage	36
Fermentation inhibitors	18	Good quality silage	38
Mineral acids	18	Feeding Value of Silages	39
Organic acids	18	Nutrient content of hays and silages	39
Non-Acid fermentation inhibitors	19	Voluntary consumption of hays and silages	39
Fermentation stimulants	19	How much silage should be fed	39
Cellulolytic enzymes	19	Feeding silage to different classes of livestock	40
Amylolytic enzymes	19	Special problems with feeding silage	40
Microbial inoculants	19	Nutrient content of silages	41
Molasses and sugars	19	Costs of Silage Production	44
Aerobic inhibitors	20	Selecting a forage system	44

Page

Estimating costs	44
Production assumptions	44
Fixed costs	44
Variable costs	45
Total costs	45
Comparing two silage systems of different sizes	48
Comparison of harvesting 500 tonnes of dry matter as silage versus round bales	49
Comparing costs of silage-making by different systems and sizes	50
Benefits	51
Investment analysis	51
Appendix	52

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INTRODUCTION

Preserving and storing an adequate and nutritionally suitable winter feed supply is an essential part of livestock production in western Canada. With feed costs making up a major portion of total livestock industry expenses it is essential that the most efficient and effective method be used. Silage offers the opportunity of consistently putting up high quality feed with a minimum of harvesting losses despite weather. Timely harvesting will minimize losses resulting in silage of a high quality. The ensiling process itself does not affect the quality of the feed.

Low quality silage can result from a lack of understanding of the process, poor planning, or inadequate or imbalanced equipment, labor, or storage facilities. Before making a long term commitment to put up silage, it is necessary to estimate the relative merits of various systems, especially total costs, availability of labor, need for consistent high quality feed, how well harvesting utilizes existing equipment and can be integrated with other farm operations. If a silage system is selected it pays to understand the process well and to do it correctly.

Advantages of silage compared to hay

The major advantage of silage is that the crop can be harvested when it is ready in almost all weather conditions.

Since there are fewer harvesting losses, more nutrients are harvested per acre compared with most other systems (see table 13 comparing dry matter losses with various harvesting systems). Ensiling permits the use of a wider range of crops including corn, fababeans and sunflowers which are difficult to preserve by other methods. It offers a practical method of salvaging weedy, hail damaged, frozen or otherwise damaged crops to produce a palatable and nutritional feed supply.

Silage can be put up and stored in large quantities of

uniform quality requiring minimal adjustments to the ration fed. Feeding silage also reduces many feeding problems including difficulties with starting cattle on feed, bloat and elimination of dust. It minimizes the need for feed processing.

Disadvantages of silage

The major disadvantages of silage compared with hay are that it requires more labor and time. Economies of scale and labor requirements can be met by working with neighbors. Capital costs and total costs per ton (tonne) harvested can be high or low depending on the total tonnage harvested and the system used. Used silage structures have limited market value.

Silage is heavy, so long distance hauling is inefficient. It must be produced near the location where it will be fed. Silage has limited market potential.

Silage odor is offensive to many people and this should be considered when choosing storage locations.

Silage relative to other production

Making silage fits in well with most other farming operations. By ensiling cereals, you reduce the number of acres that must be combined. Early ensiling also makes it easier to do fall cultivation, fertilization, etc. As mentioned, silage offers a mechanism for salvaging crops that would be useless for other purposes.

Silage crops that are harvested early are better companion crops for perennial forages than crops which are left to mature for grain. Reducing seeding rates and nitrogen fertilization rates for the silage crop will result in less competition to the establishing forage crop.

CROPS FOR SILAGE

Any green crop which has adequate water-soluble carbohydrates and the correct moisture content can be ensiled. Feeding value is related to the nutrient content of the crop species (e.g., grasses and cereals are generally lower in protein than legumes) and to crop maturity. Less mature crops are generally higher in protein and energy than more mature crops. An exception to this rule is corn, where energy levels are more or less maintained as maturity advances through stages suitable for silage making.

While the feeding value of crops is not greatly affected by ensiling, palatability or acceptability to livestock may be improved. For example, sweet-clover is more palatable as silage, and voluntary intake by livestock will be increased resulting in improved animal performance. Ensiling frequently permits the use of weedy, hauled or frozen crops.

Annual crops for silage

Most silage on the prairies is made from annual crops, especially cereals. Producing annuals for silage is similar to producing them for commercial seed or grain except that crop inputs are directed to optimizing total dry matter yield. Regional yield comparisons of commonly used annuals are listed in tables 1A, 1B and 1C.

Quality is similar between varieties of a crop species. The differences between similar crops, such as the various cereal crops, is less than that between very different crops such as cereals compared to legumes. Protein quality comparisons are listed in figure 1.

TABLE 1A. AVERAGE DRY MATTER FORAGE YIELD INDEXES (PER CENT OF OATS) FOR ALBERTA

	Avg. % crude protein	Brown soil Brooks Bigstone	Brown soil Brooks (Irr.)	Dk. Brown soil Standard (Irr.)	Black soil Lacombe Olds-Cremona Westlock	Solonchic soil Vegre- ville	Grey-Wooded soil Bluffton Rocky Mtn. House Smoky Lake
Oats	8.9	100	100	100	100	100	100
Barley	10.2	117	130	105	77	80	72
Spring rye	9.6	101	108	112	71	94	68
Triticale	9.7	102	114	111	81	96	75
Field peas	17.9	75	83	95	55	78	69
Fababeans	19.1	45	82	77	62	50	62
Corn	8.5	45	172	84	80	61	71
Sunflowers	11.6	109	163	137	88	136	91
Oat Yield lb/ac		4340	7920	7720	8949	5295	6281
kg/ha		4860	8870	8646	10023	5930	7035

Brooks Horticultural Station and Agriculture Canada Research Station, Lacombe, Annual Forage Trials 1979-83.

TABLE 1B. WESTERN CANADIAN YIELDS OF ANNUALS FOR SILAGE lb/ac (kg/ha)

Species	Location				
	Alberta		Saskatchewan		Manitoba
	Brooks (Irr.) (1984-86 Average)	Lacombe (1984-86 Average)	Swift Current (1984-86 Average) Drought in 1985	Saskatoon (1985-86 Average)	Brandon - Clay/loam (1984-86 Average)
Oats	11,990 (10,702)	11,670 (10,417)	2,230 (1,994)	7,070 (6,315)	3,380 (3,022)
Barley	13,740 (12,268)	10,390 (9,279)	2,100 (1,872)	9,040 (8,074)	4,210 (3,762)
Triticale	13,160 (11,750)	10,630 (9,490)	2,300 (2,052)	6,550 (5,851)	3,410 (3,049)
Feed Wheat	-	-	1,930 (1,725)	7,060 (6,304)	-
Peas	6,390 (5,707)	8,950 (7,992)	2,100 (1,874)	7,740 (6,912)	2,750 (2,451)
Fababeans	14,300 (12,768) (1984-86 average)	8,580 (7,658)	-	7,450 (6,649)	2,600 (2,323) (1985-86 average)
Corn	15,750 (14,063)	7,050 (6,294)	1,900 (1,697)	12,360 (11,036)	3,020 (2,695)

Adapted from CDA Cooperative Tests 1984-86.

TABLE 1C. MELFORT YIELD OF ANNUALS FOR FORAGE

Crop	Dry Matter Yield 1985-87	
	lb/ac	kg/ha
Barley	7970	7120
Canola - Argentine (<i>Brassica napus</i>)	7740	6910
Canola - Polish (<i>Brassica campestris</i>)	6350	5670
Fababeans	5850	5220
Field Peas	6340	5660
Lentils	4280	3820
Wheat	7090	6330

7 Station Years - Data from three soil types in N.E. Saskatchewan.

Crop	Dry Matter Yield 1974-76	
	lb/ac	kg/ha
Corn	10430	9310
Oats	8720	7790

Agriculture Canada Research Station, Melfort.

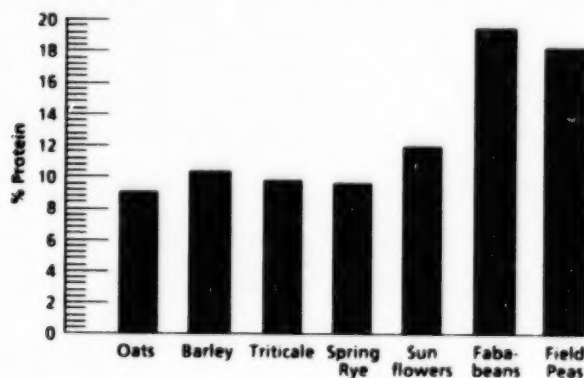


Figure 1. Average per cent protein of silage crops Lacombe Research Station 1980-83

There can be variations in quality from year to year. For example, a four year comparison from the Lacombe Research Station showed Grizzly oats gave crude protein percentages from 7.1 to 9.3.

Cereal silage

Cereals are easily ensiled since water soluble carbohydrate levels are high, buffering capacity is low, and moisture content is easily controlled. Since quality, especially protein content, is relatively low, cereals should be harvested before they get too mature. The maximum total yield and total protein is obtained by harvesting at or before the soft dough stage, depending on the species. At this stage moisture content is usually about 65 per cent so that the crop should be ensiled very soon after swathing. For lengthening the period of harvest it is usually better to use high yielding varieties or species with varying maturity dates rather than to delay seeding with one variety. Using one variety seeded at various dates usually results in lower overall yields.

If feeding requirements indicate a need for higher protein than that provided by cereals in the soft dough stage, this may be obtained by harvesting at an earlier stage of maturity. This will mean that dry matter yield is much lower so the econom-

ics of using higher quality crops versus cutting later and providing protein supplements should be considered.

For a guide to assist in variety selection see Appendix 1.

Barley

Barley is a high yielding cereal under irrigation in Alberta and Saskatchewan. It is also relatively high yielding for dryland production in Brown and Dark Brown soil areas provided there is adequate soil moisture. An assessment of stored soil moisture should be made in the spring before planting barley or other cereals for silage in the Brown soil area, since summer rainfall may not be adequate to meet the needs of the crop.



Figure 2. Swathing barley for silage

In the Black soil zone, barley has a lower dry matter yield than oats, except in the most southwesterly part of Alberta (Longview), where it yields more. Barley silage is higher in quality and this compensates for slightly lower yields. Barley is very responsive to intensive production and will give a relatively higher yield with increased fertilizer rates, etc. It is also used to some extent in Grey Wooded soil areas but lower yield and lack of adaptability to factors such as acidity and excessive soil moisture limit its usefulness in some places.

Barley is more tolerant of saline soils than other cereals. Barley yields 50 per cent of normal on a soil with an electrical conductivity of about 8 to 9 mmhos/cm compared to wheat which gives 50 per cent of normal yield at about 7 mmhos/cm. Barley is less tolerant of acid soils than oats. Barley is earlier maturing than other cereals and may be planted in May to early June in parkland and Peace River areas. In southern areas the planting date is less critical, but late May seeding is recommended. Early maturity does mean that barley is a good choice when very late seeding is necessary. For silage production both two-row and six-row barley varieties should be seeded at 75-110 lb/ac (84-123 kg/ha). The higher rates are used with higher soil moisture conditions. As for grain, high rates of fertilizer, especially nitrogen, are required for high silage yields. Barley has less lodging resistance than other cereals, except oats, and the use of high nitrogen fertilizer increases this problem. There are varietal differences in lodging resistance. Both rough and smooth awned types are satisfactory for silage making.

Since barley is an early maturing crop with some drought tolerance it has a low water requirement. In irrigated areas maximum silage yields can be obtained with a total of 15-16 in. (375-450 mm) of water. If 8 in. (200 mm) of moisture is available from soil storage and rainfall, then about 6-7 in.

(150-175 mm) of irrigation water is required. Moisture stress at the time of tiller initiation and development will reduce yield. Water requirements are highest from the shot blade stage to the time of kernel formation. High soil moisture during the jointing and boot stages promotes vegetative growth but does increase lodging (see *Irrigation Management of Barley*, Alberta Agriculture, Agdex 561-15, or *Irrigation of Cereal Crops - Development vs. Water Use*, Irrigation Branch, Saskatchewan Water Corp., ISBN0-88656-276-7 for more information).

For ensiling with horizontal silos, harvest should be completed by the time the standing crop drops to 65 per cent moisture since some moisture is lost during harvest. In central Alberta the moisture content of standing barley drops by about 1 per cent per day. The 65 per cent moisture level occurs about three weeks after heading, i.e., at the early dough stage (see figure 3).

Figures 3, 4, 5 and table 2 show per cent moisture, total yield, relative yield and per cent digestibility of oats, triticale and barley on Black soil.

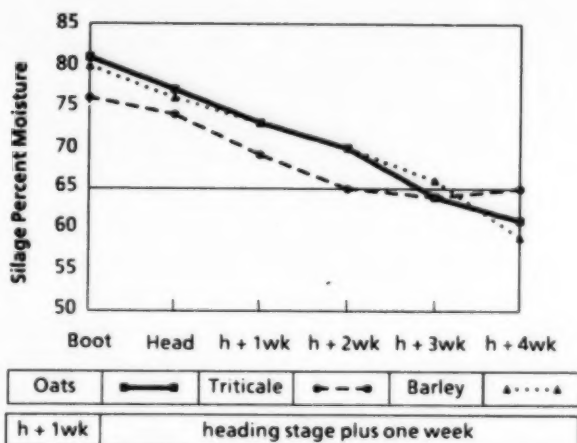


Figure 3. Silage percent moisture

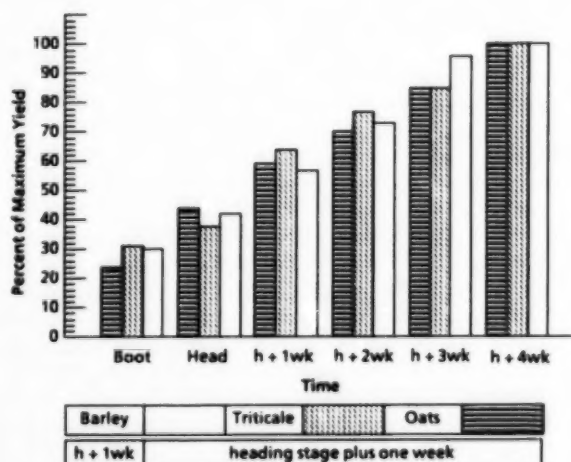


Figure 4. Percent of total yield vs. maturity

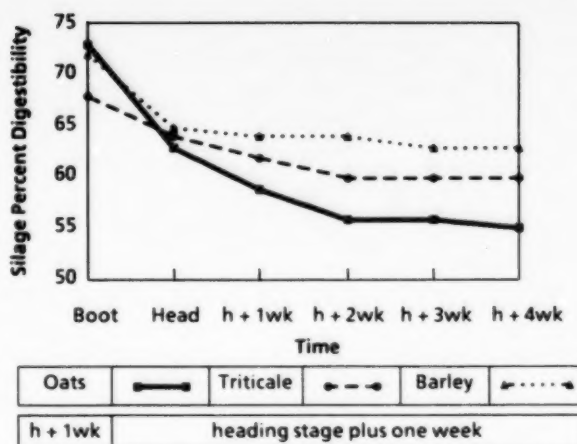


Figure 5. Silage digestibility (in vitro digestibility)

TABLE 2. TOTAL YIELD kg/ha

Maturity	Oats	Triticale	Barley
Boot	1,680	1,809	2,093
Head	3,149	2,260	2,980
H + 1 week ¹	4,196	3,770	4,000
H + 2 weeks	4,980	4,578	5,160
H + 3 weeks	6,073	6,040	6,778
H + 4 weeks	7,113	5,920	7,070

¹H + 1 week is heading stage plus one week.

Notes for Figures 3, 4, 5 and Table 2

Oats and triticale reached the heading stage in 69 days; barley in 63 days.

Maturity was as follows:

Oats - Heading plus 2 weeks was medium milk, heading plus 3 weeks was late milk and heading plus 4 weeks was the early dough stage.

Triticale - Heading plus 3 weeks was early milk and heading plus 4 weeks was the watery dough stage.

Barley - Heading plus 2 weeks was watery dough, heading plus 3 weeks was early dough and heading plus 4 weeks was the soft dough stage.

Cereals are considered to be headed when 50 per cent of the heads on the main tiller are above the boot.

Unpublished data, V. Baron, Agriculture Canada Research Station, Lacombe, 1985.

Comparing total yield of standing cereals at 65 per cent moisture instead of at maximum dry matter yield shows barley yield to be relatively higher. For example, at Lacombe at 65 per cent moisture there was a slight yield advantage of barley over oats or triticale (see figure 3 and table 2). Barley also has a higher per cent digestibility than other cereals except wheat. Again Lacombe data showed barley had 63 per cent digestibility at three weeks past heading compared with oats at 56 per cent and triticale at 60 per cent (see figure 5). For production rations, increased digestibility is associated with higher levels of dry matter intake when the percentage of digestible dry matter is below 70 per cent.

Barley also has higher per cent protein compared with other cereals at a similar stage of maturity (see figure 1 and table 1A). Higher protein content but lower yield can also be obtained by harvesting earlier. For example, research at Brooks (AHRC Pamphlet 84-6, p. 53) indicated the highest protein content is attained from the boot-to-head-emerged-stage but yields are approximately one-half those at the dough stage.

Oats

Oats yield the highest total dry matter and total energy of all cereals in the Grey Wooded soil areas. They yield more total dry matter but not necessarily more digestible material per acre than other cereals on Black soils (see figure 4 and 5 and table 2). Oats are recommended for silage production on Dark Brown soils but are lower yielding than some other cereals.

Compared with other cereals, oats are more tolerant of acid soils and of excessive soil moisture but are less tolerant of salinity than barley or wheat. They are also intolerant of manganese deficiency which is associated with a physiological disease known as grey speck. Manganese deficiency is often associated with low lying, high organic matter soils (i.e., cold soils) and sandy soils.

Oat varieties most suited to fodder production may be different from those which give the greatest grain yield. There are also differences in lodging resistance and in days to maturity between varieties. Lodging is a more frequent problem when oats are grown with high fertilizer inputs, especially nitrogen, and when soil moisture levels are good.

Recommended planting rates for oats for silage production range from 65 to 115 lb/ac (73-129 kg/ha). The higher planting rates result in less tillering, finer stems and decreased plant height. The lower planting rates are advantageous in drier areas. The planting rate does not have a significant effect on silage quality. The optimum time to plant oats for silage production is about mid-May in northern and central regions, and late May in the south. Planting later will result in decreased yields.

Lacombe data indicate that the moisture content of standing oats dropped to 65 per cent at about three weeks after heading, i.e., the late milk stage (see figure 3). At the late milk stage oats had produced about 85 per cent of maximum total yield (see figure 4 and table 2). Although maximum total yield was reached at the early dough stage, delaying harvest until this time would result in greater storage losses from aeration using horizontal silos.

Energy levels per pound (or kg) are high in early growth stages but they gradually decline with maturity and level off when the kernels begin to develop (see figure 6).

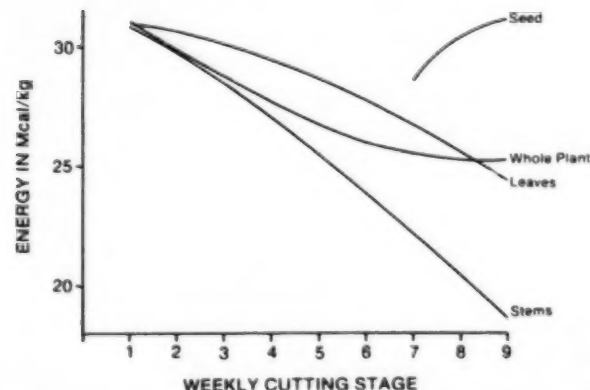


Figure 6. Energy value of the major plant components at progressive stages of development of oats (pooled values for three varieties)

The per cent digestibility of oats at normal ensiling stages is slightly lower than other cereals (see figure 5). When comparing total dry matter yields of oats to other cereals the lower digestibility of oats should be considered.

The protein quality of oats is lower than that of other cereals (see figure 1 and table 1A). The proportion of crude protein does not usually drop below about 8 per cent since the developing seed contributes to protein content from the milk stage onwards (see figure 7). Total amount of protein per acre or hectare continues to increase until the dough stage.

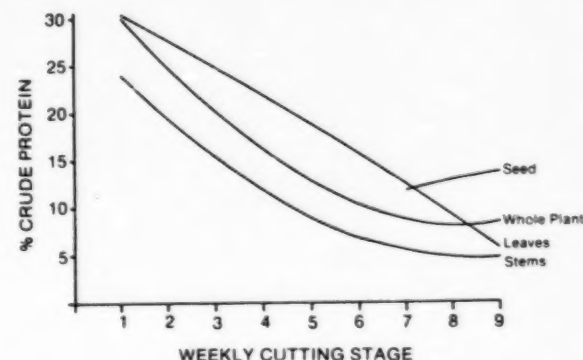


Figure 7. Crude protein of major plant components at progressive stages of oat development (pooled values for three cultivars)

Notes for Figures 6 and 7

Cutting stages were as follows: 1 and 2 - leaf, 3 - boot, 4 - heading, 5 - early bloom, 6 - late bloom, 7 - milk, 8 - dough and 9 - ripe.

Agriculture Canada Research Station, Swift Current, 1973.

Triticale

Triticale is a relatively new cereal crop. Although slightly lower yielding than barley, it has done well in the Dark Brown soil zone, especially under irrigation. Its tall growth is an advantage under dryland conditions. Licensed varieties have yielded somewhat less than oats in the Black and especially the Grey Wooded soil areas, but some breeder lines under initial testing have given improved yields. Triticale should be planted in early to mid May in central and northern areas, and late May in southern regions at about 85-150 lb/ac (95-168 kg/ha) for silage production.

The main advantages of triticale include superior lodging resistance and late maturity. The moisture content of triticale at Lacombe was still 65 per cent at four weeks after heading, i.e., the watery dough stage (see figure 3). At the watery dough stage total yield of triticale was almost as much as oats at three weeks past heading, i.e., when oats harvest should be completed (see table 2), and digestibility was intermediate between oats and barley (see figure 5). The late maturity of triticale permits producers with a large silage acreage to extend harvest over a longer duration and maintain good quality by avoiding the ensiling of over-ripe cereals. The protein content of triticale is intermediate between oats and barley (see figure 1 and table 1A).

Spring wheat

Although not commonly used for silage, spring wheat is a satisfactory crop for this purpose. It yields well in the Brown soil zone, especially under irrigation. Wheat is intermediate between oats and barley for tolerance to salinity and acidity. Wheat tolerates about 7 mmhos/cm salinity as measured by electrical conductivity (compared with 8 mmhos/cm for barley) and a pH of 5.5 (compared with 4.5 for oats). Wheat should be planted from mid to late May at about 75-110 lb/ac when grown for silage production. Utility wheat varieties are most used for silage, but hard red spring wheat varieties are better adapted to severe drought. Soft white wheat has yielded well for silage under irrigation in southern Alberta.

Nutrient quality is satisfactory compared to other cereals. For example, at Brooks under irrigation, wheat varieties had 12.2 per cent protein on four years of tests compared to barley at 11.8 per cent, oats at 11.7 per cent, and triticale at 11.6 per cent. On the same tests wheat varieties had 29.6 per cent acid detergent fibre compared with barley at 26.5 per cent, oats at 31.5 per cent and triticale at 30.1 per cent. Wheat should be harvested in the early dough stage for most uses.

Winter wheat

Spring seeded winter wheat gives low silage yields and requires at least two cuttings. Mixing winter wheat with another cereal may have benefits provided the regrowth is used as pasture. Brooks data indicate barley plus winter wheat yielded 94 per cent as much silage as barley alone, but in addition it produced two simulated pasture clippings which gave a total of 20 per cent more yield (A.H.R.C. Pamphlet 84-6, Table 64).

Fall seeded winter wheat has a growth habit similar to that of spring seeded cereals. However, yield is somewhat less and more variable than for other cereals because of winter kill, it is therefore, less reliable as a silage crop. Its early maturity does extend the silage harvesting season.

Spring rye

Spring rye is adapted to the Brown and Dark Brown soil areas, especially under irrigation. In these areas yields are more or less comparable to those of other cereals. It also does well in the Black soils of southwestern Alberta. Crop height is somewhat greater and this may be an advantage under dryland production in dry seasons. Spring rye should be planted from mid to late May at 85-140 lb/ac (95-157 kg/ha) when grown for silage.

Quality is comparable with that of other cereals. At Brooks, under irrigation, spring rye had 10.6 per cent protein and 30.1 per cent acid detergent fibre over four test years.

Fall rye

Fall rye yields well in all soil zones. It is very winter hardy and has the advantage of utilizing good spring moisture to promote early growth. This quality is especially useful on sandy soils that have low water holding capabilities, and in areas of lower rainfall. Fall rye is capable of producing an early crop of silage and lengthening the silage making season.

Fall rye should be seeded August 1 - September 15. The more northerly the growing area, the earlier it should be seeded. A seeding rate of 1.0 to 2.0 bushels/acre will provide a sufficient number of plants for a good yield. Fall rye will tiller profusely provided adequate soil moisture and nutrients are present.

For maximum silage yields it is recommended that one not graze fall rye in the spring or fall.

Fall rye for silage is ready two to four weeks earlier than most cereal silages. It should be cut at the milk to early dough stage. If allowed to mature too long, ergot bodies may form. These ergot bodies may cause abortions in livestock.

The quality of fall rye silage is comparable to that of other cereal crop silage. Total dry matter yields of fall rye are generally lower than those of oats, but in some cases will outyield barley.

Field peas

Field peas are cool season annual legumes. Since field peas have limited root systems, they lack tolerance to extreme drought or hot weather. High temperatures during flowering causes blasting which results in decreased pod set. This is significant for silage production since pod development makes up part of the yield. Field peas are recommended for silage production in Grey Wooded and Black soil areas and in irrigated areas. In Alberta field peas have outyielded fababeans on Grey Wooded, Solnetzic and Black soils in southwestern Alberta although they have yielded less than fababeans on other Black soils. In Saskatchewan, field peas have yielded slightly more than fababeans. Field peas are considerably lower in total dry matter yield than cereals, and this must be carefully considered when planning a cropping program. For example, at Brooks under irrigation barley yields 57 per cent more total dry matter than field peas (see table 1A).

Field peas do best on loam, clay loam and sandy loam soils. Soils with poor internal drainage or cold soils (e.g., organic soils) are not well suited to field pea production since seedling and root diseases are more prevalent under these conditions. This crop has a low tolerance to soil salinity. Peas should not be grown on land which has produced legumes or oilseeds in the past four years owing to the possible presence of soil-borne diseases. Field peas are therefore most suitable following continuous cropping with disease-resistant crops such as cereals.

The decision to grow field peas for silage should be based on the need for higher quality rather than yield and costs of production. Peas generally yield less total dry matter and digestible energy than cereals alone (see figure 8 and table 1A, B, C). The advantage of peas is that they yield a higher percentage of protein and total protein per acre (see figure 8). Field peas should be seeded as early as possible in May when soil temperature has reached 4-5°C in the top 0.5-1.0 in. (2.5-5 cm).

The seedlings have good tolerance to frost and can regrow from buds below the soil surface if the main shoot is killed by severe frost. Early seeding helps to avoid flower blast since the full flower stage is reached before the heat of summer (i.e., before mid July). Early shallow cultivation is recommended to control weeds and warm the soil before seeding but still conserve moisture and keep the seedbed firm. A seeding depth of 2 to 3 in. (5-7.5 cm) in 6 in. (15 cm) row spaces is recommended. Conventional seed drills are satisfactory for seeding although they must be adjusted carefully to avoid cracking or chipping seed, especially with larger seeded varieties. Slow travel speeds while seeding will decrease seed damage and help to maintain an even seeding depth. A seeding rate of one seed per 3 in. (7.5-8 cm) within the rows is satisfactory assuming the use of 6 in. (15 cm) row

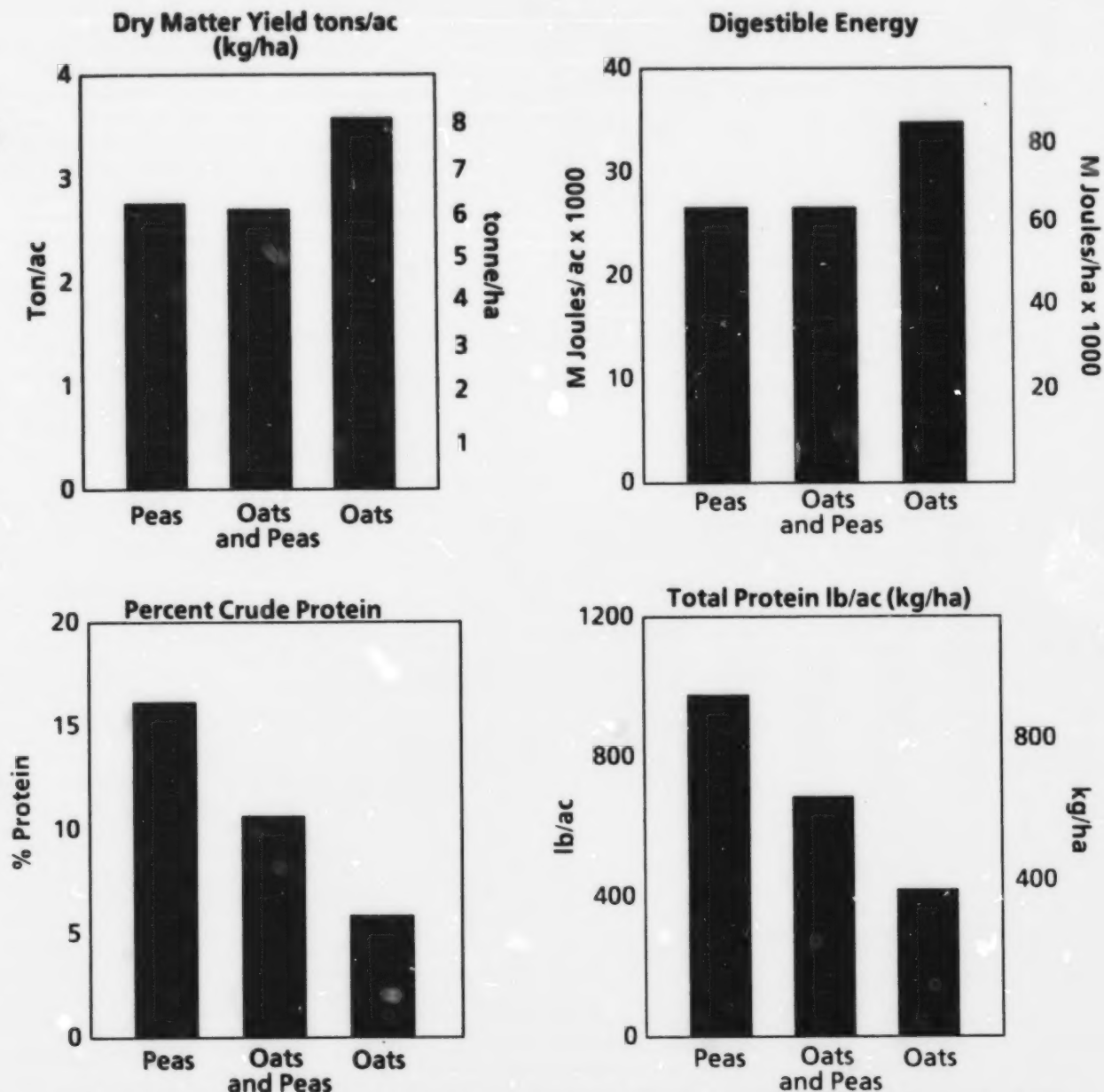


Figure 8. Yield of peas and oats on Grey wooded soil, Bluffton Alberta, 1981-83 (CDA Lacombe Test)

space and good seedling emergence. This is about 160-200 lb/ac for large seeded varieties and 110 lb/ac for small seeded varieties. Seed should be treated with recommended fungicides to control fungal diseases. Viable inoculant should be stuck onto the seed just prior to seeding to ensure optimum nitrogen fixation. Soil tests should be used to determine phosphorus and other fertilizer requirements.

For variety recommendations see Appendix 1.

Field peas are poor competitors with weeds. Recommended herbicides are given in publications listed in Appendix 1.

Field peas are sensitive to moisture stress during flower production and pod set. The total water requirement of field peas from all sources of water including stored moisture,

rainfall and irrigation is 18 in. (450 mm). If 8 in. (200 mm) of moisture is available from soil storage and precipitation, then another 8-10 in. (200-250 mm) of irrigation water should be applied for good yield. Excessive irrigation on poorly drained soil will encourage disease development.

Since peas are poor competitors they will yield best in pure stands. However, they lodge readily so swathing is difficult. Low cutter bar heights, lifter guards and pick up reels must be used. Pure peas are difficult to ensile since water soluble carbohydrate levels are low, buffering capacity is high and moisture content is high. Before ensiling the crop must be wilted to 65 per cent moisture. Peas should be harvested when the earliest pods begin to wilt and wrinkle but before shattering occurs.



Figure 9. Lifter guards are helpful for harvesting peas

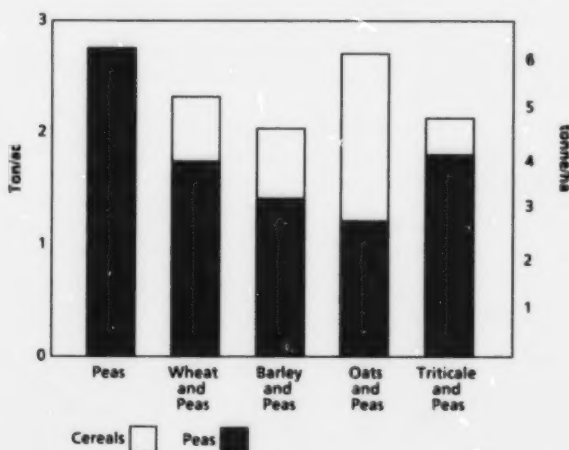


Figure 10. Dry matter yield of cereals and peas on Grey wooded soil, Bluffton Alberta, 1981-83.

Cereal-pea mixtures are sometimes grown to provide improved quality as compared with cereals alone, to support the peas for easier harvest, and to improve silage making as compared with peas alone. For mixtures, the cereal planting rate should be reduced by much more than half of normal, i.e., 18 lb/ac [20 kg/ha] for oats or barley and about 27 lb/ac [30 kg/ha] for wheat or triticale. The cereal should be cross-seeded. The field pea planting rate should be maintained close to the amounts for pure stands to maintain a significant portion of peas in the silage. Oats and barley are more competitive than wheat and triticale (see figure 10). Field peas are more competitive than fababeans in a mixture. For example on Black soil at Lacombe peas alone yielded 61 per cent as much as fababeans alone, while an oat-pea mixture yielded 3 per cent more than an oat-fababean mixture (Lacombe Research Station Highlights, 1986).

A pea-cereal mixture can be made by growing the crops in adjacent strips (see Fababeans). This makes fertilization and weed control for each crop much more feasible than growing mixtures. It also permits taking full advantage of the legume in the rotation provided the strips of peas are wide enough.

Fababeans

Fababeans are upright-growing annual legumes which are resistant to lodging, and are very sensitive to drought. This crop is recommended for silage production in the Black and Grey Wooded soil areas and in the irrigated areas.

Fababeans produce less dry matter than most other crops (see table 1A, B, and C). The main advantage of this crop for silage is its high quality, especially high protein content. In most Black soil areas in central Alberta, fababeans outyield field peas and produce silage with a slightly higher protein content (see table 1A).

The decision to use fababeans for silage must be made on the need for high quality feed, especially high protein. The disadvantage of fababeans is that they have a lower dry matter yield, a higher production cost, especially seed cost, and are more difficult to ensile than cereals.

Fababeans do well on most soil textures provided moisture is adequate, although deep medium-textured soils are preferred. Fababeans tolerate more flooding than most crops although growth is affected by lengthy flooding. This crop does poorly on shallow soils with a compacted layer near the surface, such as solonchaks. They are sensitive to salinity (i.e., conductivity over 3 millimhos/cm). Fababeans are legumes and fit well into most crop rotations. The crop is generally grown after a cereal rather than on summerfallow or following other nitrogen-fixing crops or oilseed crops.

Fababeans should be planted as early as possible in northern and central regions (i.e., before May 7), and by mid May in irrigated areas for best yields. The seedlings are fairly frost tolerant (i.e., to -4°C). Fababeans can regrow from buds below the soil surface if the first growth is killed by frost. The seedlings lack competitive ability and therefore should be seeded where weeds are under control or can be controlled with herbicides. The seedbed should be moderately firm with good moisture content. A seeding depth of 3-4 in. (7-10 cm) to good moisture will result in even emergence of the stand. A seeding rate of 150 lb/ac (170 kg/ha) for medium sized varieties and 180 lb/ac (200 kg/ha) for large seeded varieties is recommended. A row space of 6-7 in. (15-18 cm) is recommended. Provided there is good germination and emergence, this seeding rate and row spacing should result in about 175 thousand plants per acre (430 thousand per ha) which is about 1 plant per 6 in. within rows (or 1 plant per 13 or 14 cm). The seed drill must be adjusted for easy flow of seeds. Use a slow ground speed to avoid hairline cracks on seed as this decreases germination and seedling vigor. A slow ground speed also makes deep seeding more consistent.

Inoculate seed with viable fababean inoculant strain Q and a sticking agent just prior to seeding. This will ensure optimum nodulation and nitrogen fixation. Fababean rhizobia are noted for high nitrogen fixation. Fertilizer for phosphorus and other nutrients is determined by soil testing.

If diseases become a problem, a rotation with five years between fababeans and any other affected crop should be used.

The low dry matter yield, high quality, and difficulty in making good silage with pure fababeans makes the use of a cereal mixture a likely compromise. For mixtures the cereal seeding rate should be decreased to less than half the normal amount. The fababeans should be seeded at a rate of at least 100 lb/ac as the yield loss resulting from competition is significant. The two crops should be cross-seeded. The mixture will have a protein and energy content intermediate between cereal and fababeans depending on the final compo-

sition of the mixture. The dry matter yield of a mixture was 17 per cent less than for oats alone and 6 per cent less than for barley alone on Black soil at Lacombe (ref. to CDA Lacombe Research Highlights, 1986). At Brooks under irrigation a mixture yielded 12 per cent less dry matter than barley alone (AHRC pamphlet 84-6, table 41). Triticale and wheat were somewhat less competitive allowing a higher fababeans component compared with oats or barley at Lacombe (see figure 11). Fababeans yield less in a cereal mixture than field peas. It should be noted that only a limited number of herbicides are available for weed control of crop mixtures.

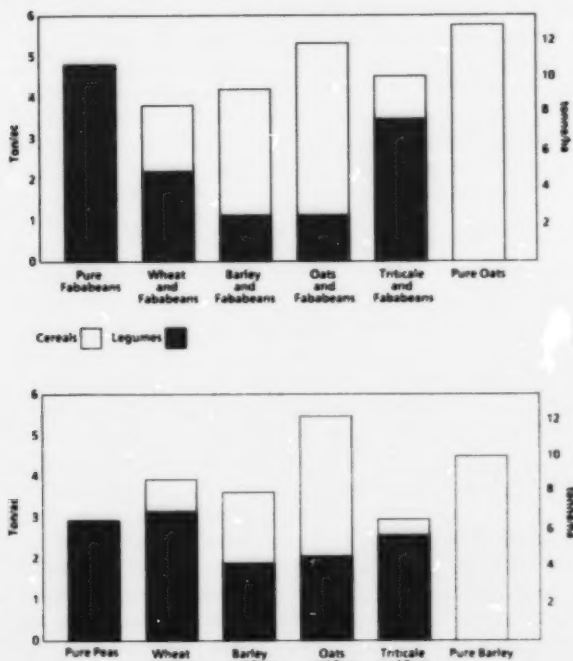


Figure 11. Total and component D.M. yield of mixtures average of 1981-83 CDA, Lacombe

An alternative to growing fababeans in a cereal mixture is to grow each in a pure stand in fairly wide strips adjacent to each other. The crops can be harvested across the strips with each load of silage containing both crops. The strips should be wide enough to maintain from year to year in rotation and to take full advantage of the nitrogen fixation from the fababeans. This also permits correct fertilization of each species, with special emphasis on nitrogen for the cereal and phosphorus for the legume.

For annual variety recommendations see *Varieties of Annual Forage Crops for Alberta*, Agdex 120/32-1, *Fababeans Production in Alberta*, Agdex 142/20-7, and *Guide to Farm Practice in Saskatchewan*. Herbicides are often necessary and spraying should be done early as fababeans lack competitive ability. See Appendix 1 for herbicide recommendations.

For irrigated production, fababeans are very responsive to the application of full water requirements. The soil should not be allowed to become drier than 60 per cent of field capacity to 2.5 feet (0-75 cm depth). A fababeans crop for

silage uses about 23 in. (580 mm) of water for good yield. If 8 in. (200 mm) of water is available from soil storage and precipitation, then 15 in. (380 mm) of irrigation water will be required. Since the crop reaches a height of about 6 ft (1.8 m) under irrigation, it is best to use pivot or flood methods.

Fababeans should be swathed when one or two of the bottom pods on one-quarter to one-third of the crop have turned brown. This gives a maximum yield of energy and protein per acre. Wilting is still very necessary at this stage. The crop is difficult to ensile owing to its high moisture content, low percentage of water soluble carbohydrates and its high buffering capacity (see the ensiling process). Fababeans silage is very dark in color but it is readily eaten by livestock.

Silage corn

Corn is frequently grown for silage production in irrigated areas receiving enough heat, i.e., a minimum of 2100 corn heat units for six out of ten seasons. Corn is the highest yielding crop for silage under irrigation in areas where heat is not limiting (see table 1A, B and C). The growth and development of corn increases rapidly from an air temperature of 10°C up to 30°C (50°F - 85°F). Under good growing conditions the production of a corn plant continues at a rapid rate until midway during the grain filling stage (see figure 12).

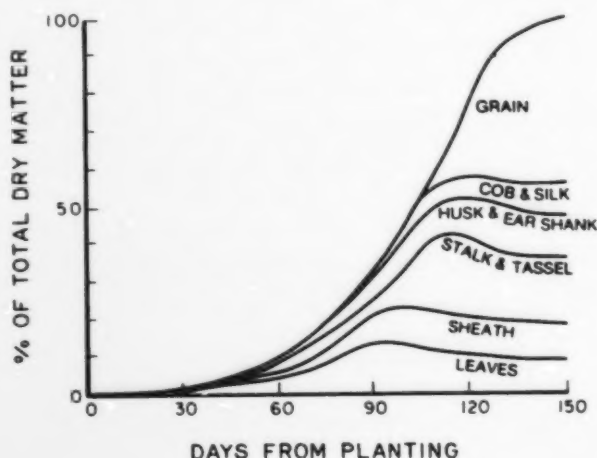


Figure 12. Relationship between distribution of dry matter in a corn plant and days from planting in Alberta (from Corn Production and Utilization in Alberta)

Despite its high yielding ability the economics of corn production should be assessed very carefully since it requires specialized equipment, higher inputs and more favorable growing conditions. Attempting to produce corn silage in areas that are too cool on average is likely to result in uneconomical production compared with growing better adapted crops. In cooler areas the crop often must be harvested when it is very high in moisture and before it has reached maximum yield.



Figure 13. Harvesting corn requires specialized equipment

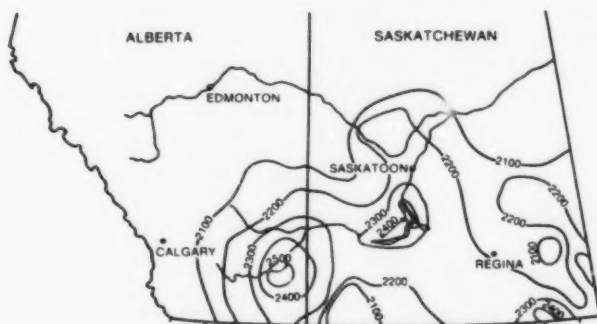


Figure 14. Average number of corn heat units received

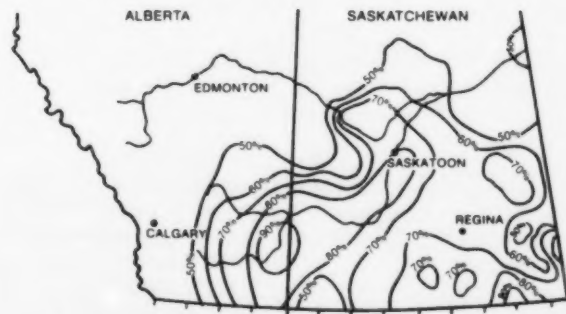


Figure 15. Probability of receiving 2100 corn heat units

Selecting a variety for corn silage production is different from selecting one for grain corn. Corn silage is normally harvested beginning at 70 per cent moisture, i.e., 200 corn heat units before maturity. Since corn for silage only needs to reach this stage by the first fall frost, the 200 corn heat unit margin of safety recommended for grain corn is not as critical. On this basis one can consider planting varieties for silage with a rating of up to 200 corn heat units more than received by the location where they will be grown. Experience will determine which varieties usually give the highest yield of the correct maturity before frost. It should be noted that a hard frost will lodge a crop with more than 75 per cent

moisture. Also a high moisture crop must be ensiled as soon as possible after a killing frost to avoid losing nutrient value.

The heat unit maps, figures 14 and 15, can be used as a general guide as to where silage corn can be produced. Slope of the land, elevation and soil type also affect the amount of heat a specific field receives. It is recommended that silage corn be grown in areas receiving an average of 2100 heat units or more. The Corn Heat Unit (CHU) system rates corn hybrids and geographic locations on a common basis. Corn development varies with temperature so a relationship between temperature and development is used as a basis for the ratings. This heat unit system treats the daytime temperature separately from night-time temperature. The daytime relationship uses 10°C as the base, below which no development occurs, and 30°C as the optimum temperature. The night-time relationship uses 4°C as the base temperature with no optimum. The contribution to Corn Heat Units by daytime (maximum) temperature is determined from the equation:

$$Y = 3.33 (T_{\max} - 10) - 0.084 (T_{\max} - 10)^2$$

where Y is the CHU value for daily maximum Celsius temperature, $T_{\max}$.

Values for night-time (minimum) temperatures are determined from the following equation:

$$X = 1.8 (T_{\min} - 4.4)$$

where X is the CHU value for daily minimum Celsius temperature, $T_{\min}$.

The two daily values, X and Y, are averaged to provide a CHU rating for each day in the corn growing season. The daily CHU's are summed over the growing season to give a seasonal rating for the site. Season CHU ratings were determined for 84 weather stations in the Prairie provinces which record daily maximum and minimum temperatures and these values were used in figure 14. (Information on corn heat units from Corn Heat Units in the Prairies, Alberta, Saskatchewan and Manitoba Corn Committees.) For additional information see the latest edition of *Corn Heat Units in the Prairies*, the Alberta Corn Committee Hybrid Recommendation list or Saskatchewan's *Forage Crop Recommendations*, ISSN 0383-3356.

Corn requires well drained soils for best production. Fine textured soils require good internal and surface drainage for satisfactory production. Corn is sensitive to salinity, i.e., about a 50 per cent yield reduction on soils having an electrical conductivity of 4.5 to 5 mmhos/cm in the top 0-12 in. (0-30 cm) layer of soil (McKenzie and Sprout, Irrigation Division, Brooks, 1976 Annual Research Report).

As with most crops a shallow seedbed should be prepared in the spring to maintain moisture and help keep the soil firm. Corn for silage should be planted in late April to the first week in May in southern Alberta and Saskatchewan. Soil temperature for germination must be at least 10°C. Early cultivation, avoiding excess trash on the soil surface and good soil moisture levels help to make early planting possible.

For silage, corn should be precision seeded at 30,000 plants per acre (75,000 per ha) for irrigation, i.e., 1 seed per 6 in. (15 cm) at 30 in. (75 cm) row space, assuming 85 per cent survival. A specialized planter is required. Plant at about 2 in. (5 cm) depth. The use of a 30 in. row space accommodates standard corn harvesting machinery. Rows should run opposite to prevailing winds to reduce wind erosion; generally rows should run north and south.

The application of 80 to 150 lb/ac (90-165 kg/ha) of actual nitrogen in addition to soil nitrogen may be economical in

irrigated areas. Phosphorus is frequently deficient and potassium is occasionally required. Fertilizer levels should be determined on the basis of carefully sampled soil tests. Granular fertilizer, especially phosphorus, is taken up by seedlings best if it is placed near the seed. However, high application rates, especially ammonium based nitrogen fertilizers (includes diammonium phosphate) too near to the seed will harm or even kill the germinating seedling. Placing fertilizer 1 in. to the side and preferably slightly deeper than the seed permits high application rates (up to 270 lb/ac or 300 kg/ha) without serious injury to the emerging seedling.

Corn is not competitive with weeds. Herbicides for weed control can be determined by referring to Appendix 1.

In irrigated areas of Alberta and Saskatchewan corn requires a total of about 20 in. of water per year. Corn, especially for silage, requires good soil moisture levels throughout the growing season until harvest. Moisture stored from the previous year plus winter and spring precipitation usually provides enough water until mid June. The water requirements of corn are high from mid July to early September and irrigation is most necessary at that time. The most critical time for moisture is during the tasselling to grain filling stages. Since corn is tall growing, either a centre pivot or surface irrigation must be used. An analysis of long term precipitation at Lethbridge indicates that for the average growing season 8 - 12 in. of water should be supplied by irrigation. Most other corn growing areas of the prairie provinces require more irrigation than Lethbridge.

Corn should be harvested for silage when the whole plant is at 60-70 per cent moisture level. At this stage the maximum energy per acre will be harvested. This stage is best identified by determining the whole plant moisture content using an accurate beam balance weigh scale and a microwave oven or other suitable means. The 60-70 per cent moisture stage coincides with the hard dough stage of kernels. A specialized chopper is required to handle the tall crop in wide rows.

Corn contains enough water-soluble carbohydrates to ensure successful ensiling although levels do drop in more advanced stages (see table 5). It has a low buffering capacity so that less acid is required to lower the pH of the ensiled material (see table 6). Corn silage has high energy levels but is fairly low (6-10 per cent) in crude protein (see figure 1 and table 1A).

Corn can be grown continuously provided that weeds, insects and diseases do not become a problem and fertility levels are kept high. Minimum tillage is used to reduce wind erosion and soil structure breakdown. Harvesting corn silage leaves very little crop residue. This is desirable in many respects, but cultivation methods which leave enough trash on the surface to minimize erosion should be used.

Sunflowers

Sunflowers are recommended for silage production in the Brown, Dark Brown and irrigated areas of the southern prairies. In the western irrigation district of Alberta it is the highest yielding crop (see table 1 under Standard). Sunflowers give high yields and reasonable quality where they are adapted. As crude fibre is quite high, digestibility is somewhat lower than with most other crops. A three year comparison at Brooks showed a total yield of 6.7 ton/ac (14,930 kg/ha) i.e., second only to corn and an ADF of 30.7 per cent. Crude protein was 16 per cent and total protein production

was second only to the forage Brassicas (see Brooks Horticultural Station pamphlet 84-6). In the Black and Grey Wooded soil areas, sunflower yields (pure or mixed with cereals) are sometimes high, but they are also highly variable since a long and warm growing season is needed for good growth. Also a lower protein content has been reported from these areas. For example, C.D.A. Lacombe trials in central Alberta showed an average of 10 per cent crude protein (F.F.F. Project No. 78-0181). This, combined with the need for specialized equipment, makes the production of sunflowers for silage questionable in the Black and Grey Wooded soil areas.

Because sunflowers are late maturing, they should be seeded as early as possible. The minimum soil temperature for sunflower germination is 7°C; since seedlings are fairly frost tolerant up to the four leaf stage, early seeding is possible. Normal seeding depth is 1-2 in. (2.5-5 cm), but if large plump seed is used a maximum depth of 5 in. (12.5 cm) to moisture may be used. Confectionery type varieties are presently most used for silage production. See Appendix 1 for annual variety recommendations. For silage production, confectionery sunflowers should be seeded at 3-5 lb/ac (3.4-5.6 kg/ha) depending on seed size. A row space of 12 in. (30 cm) is satisfactory. Where precision planting is used, a density of 20,000-30,000 plants/ac (50,000-90,000 plants/ha) in 24 in. (60 cm) rows is recommended. These are much higher seeding rates than those recommended for confectionery seed production. The higher seeding rates produce stands which are more dense with smaller stems. Lodging and disease problems do increase as stand density increases although these problems are less serious with silage production. Low seeding rates give a slightly less total yield and the stems grow larger and are more difficult to handle.

Sunflowers are poor competitors, especially in the early stages of growth. The use of row cultivation and band spraying are possible if wide row spaces are used. See Appendix 1 for annual herbicide recommendations.

Sunflowers require high amounts of nitrogen fertilizer with applications of up to 150 lb/ac (170 kg/ha) being economic in irrigated areas. Applications of fertilizer should be based on soil test results.

Sunflowers are frequently affected by diseases and pests. Sclerotinia stalk and head rot may result in wilting of plants. Control measures include the use of crop rotations. Normally these diseases can be controlled by using resistant hybrid varieties. Sunflower beetles can cause serious leaf damage. More detailed information on disease and pest control in Alberta can be obtained from Alberta Agriculture, and the publication *Field Crop Insect Control* in Saskatchewan.

The total water requirement for sunflowers is approximately 20-22 in. (500-550 mm). If 8 in. (200 mm) of moisture is available from soil storage and precipitation, then 14 in. (350 mm) of irrigation water will be required for good yields. Since sunflowers are tall growing, pivot or flood type irrigation is most suitable.

Sunflowers should be harvested when the backs of the heads turn yellow and the bracts around the head turn brown, but before the bottom leaves drop off. High moisture may be a problem and since sunflowers don't wilt down well after cutting (they tend to rot), the crop may have to be left until it freezes before ensiling. A fine chop is required to pack coarse stems adequately. As the crop may be 6 feet (1.8 m) or more in height, specialized harvesting equipment may be needed. Sunflowers have a medium level of water-soluble carbohydrates and buffering capacity making ensiling easy.

Sorghum-sudangrass

Sorghum-sudangrass is not grown extensively on the prairies, but in recent years hybrids have produced acceptable yields in high heat areas where moisture is limited. Sorghum-sudangrasses vary in yield, growth habit and prussic acid content depending on the hybrid grown.

A well prepared, firm, moist and warm seedbed is best. The sorghums are warm-season crops and are poor competitors with weeds. Sorghum-sudangrasses do not grow well in low areas or sloughs because they are not tolerant of cool or saline soils.

The ideal time to plant is when the soil temperature has reached 18°C (65°F) (usually early June). A warm seedbed is a must to ensure even germination.

Plant 1 to 1.5 inches (2.5 - 4 cm) deep on medium and heavy textured soils. On sandy soils it may be necessary to plant 1.5 to 2 inches (4-5 cm) deep to maintain adequate moisture levels near the seed for rapid germination and emergence.

Table 3 provides a guideline for seeding rates. Consult commercial literature for the specific hybrid being planted. If the crop is seeded crossways or diagonally to the planned direction of swathing, the swath will lie on top of the stubble.

TABLE 3. SEEDING RATE GUIDELINES FOR SORGHUM AND SUDANGRASS VARIETIES, HYBRIDS AND CROSSES

Row spacing and sorghum type	Dryland	Irrigation
6 in. to 7 in. Row Spacing Sudangrass varieties and hybrids, sorghum-sudangrass crosses	15 to 25	30
30 in. row spacing Forage sorghum varieties, hybrids and crosses	5 to 8	10 to 12
36 in. to 42 in. row spacing Forage sorghum varieties, hybrids and crosses	5 to 8	8 to 10

Harvesting: Cutting sorghum-sudangrass at the start of tasseling will provide a good balance between protein content and yield. In southern Saskatchewan 90 per cent dry matter yields for sorghum-sudangrass silage in 1986 ranged from 1.6 to 4.8 tons per acre with an average of 2.7 tons per acre. This is compared with barley and wheat silage yields of 2.5 tons per acre. Sorghum-sudangrasses should be wilted before ensiling since they are very high in moisture.

Hazards with sorghum-sudangrass use: Poisoning from prussic acid (HCN) is the greatest risk. HCN poisoning causes asphyxiation. Livestock may be poisoned if they consume large amounts of forage with a prussic acid content above 0.02 per cent. Plants usually have more prussic acid if the soil is high in nitrogen and deficient in phosphorus and potassium, or if the field is under stress by drought or frost. Silage from sorghum-sudangrass can be more safely fed after a storage period of one or two months since the HCN gas escapes during storage and feeding.

A feed test is recommended to determine levels of both prussic acid and nitrates.

Feeding value: Analyses of sorghum-sudangrass silage produced in southern Saskatchewan in 1986 indicated an average protein content of 11.5 per cent (range of 7.7 to

16.4 per cent). TDN averaged 51 per cent (range of 49 to 55 per cent) and the moisture content varied from 60 per cent to 70 per cent.

Perennial grasses

Various perennial tame forages are adapted to western Canada. The most widely grown tame grasses include smooth brome grass, crested wheat grass and timothy. Tame and native grasses are fairly easy to ensile since they are low in buffering capacity and high in dry matter content. Per cent water-soluble carbohydrates varies from species to species but is adequate in most cases (see *The Ensiling Process*). At early stages of maturity (i.e., heading to bloom stage) they are medium in quality (protein and energy). Quality drops rapidly as maturity advances however. Quality information is given in tables 21, 22, and 23, pages 42 and 43. Also dry matter content increases with advancing maturity so that fine cutting or mixing with more moist material may be necessary if more mature grass must be ensiled.

Timothy grass requires especially careful timing for harvest since it is weakened by cutting during the boot stage which reduces root carbohydrate storage significantly. Timothy has a slightly lower protein content than most other grasses so cutting should not be delayed too long. Other tame grasses can be harvested at the boot stage if a higher than normal nutrient content is desired.

Overall crop management of grasses for silage is similar to that for hay production. Additional information may be found in the *Alberta Forage Manual*, Agdex 120/20-4 and in *Varieties of Perennial Hay and Pasture Crops for Alberta*, Agdex 120/32 and Saskatchewan (ISSN0383-3356).

Perennial and biennial legumes

Legume crops are very high in quality and when properly ensiled they produce excellent silage. Quality information is given in tables 21, 22, and 23, pages 42 and 43. However, they are low in water soluble carbohydrates, high in buffering capacity and this, combined with a high moisture content, makes them difficult to ensile (see tables 5 and 6). Swathing and wilting are necessary to reduce the moisture content before ensiling. The use of grass-legume mixtures improves the silage making potential, although it also results in lower protein and energy levels in the feed.

Alfalfa

Alfalfa is broadly adapted and can be produced in all soil zones of Alberta and Saskatchewan. It requires good internal soil drainage and is intolerant of acidity (i.e., intolerant of pH below about 6.0).

The general comments on legume silage making apply to alfalfa. However, alfalfa is not as difficult to ensile as most other legumes. It has a higher dry matter content than common clovers such as red clover (see tables 5 and 6). This should not be interpreted to mean that alfalfa is easily ensiled, however. Close attention to wilting and packing procedures, etc., are required to make good alfalfa silage.

Alfalfa is noted for its good yielding ability and very high quality. Alfalfa cut when 10 per cent of the plants show first bloom will have a crude protein content of approximately 17-19 per cent.

Sweet-clover

Sweet-clover is a biennial legume which is adapted to all soil zones of Alberta and Saskatchewan. It requires good internal soil drainage and is intolerant of acidity (intolerant of

pH below about 6.0). Sweet-clover is very high yielding and ensiling is an excellent way to harvest this crop. Sweet-clover weevils are a problem where sweet-clover is grown frequently.

Sweet-clover should be harvested when 10-20 per cent of the plants show first bloom; if left until full bloom sweet-clover becomes very stemmy and much lower in quality. Ensiling sweet-clover is similar to ensiling alfalfa. The resulting silage is more palatable than sweet-clover hay. However, special attention should be taken to avoid mold formation by carefully covering and sealing the silo. As with hay, moldy sweet-clover silage can result in high levels of dicoumarol production which causes bleeding diseases (sweet-clover disease) in livestock. Low coumarin varieties should be used. See *Special Problems With Feeding Silage* p 40 for more information.

Red clover

Red clover is adapted to the more moist areas of Alberta and Saskatchewan. It does well in Grey Wooded and Black soil zones. It is tolerant of acidity (tolerant of about pH 5.1).

Red clover is very difficult to ensile owing to its low water-soluble-carbohydrate content, combined with its very high buffering capacity and very high moisture content (see tables 5 and 6). Substantial wilting is necessary but is difficult to do without spoilage. Rotten leaves which may be present from lodging or lying in the swath too long can infest the silage with undesirable microorganisms.

Cutting red clover at the early bloom stage results in a crude protein content of 15-17 per cent. Harvesting at a later stage of maturity (e.g., full bloom) results in somewhat lower moisture levels but it also means that quality is lower.

Other common clovers including alsike clover and white clover are similar to red clover in their ensiling properties.

Overall legume crop management is similar to that for hay production. Additional information on these and other tame legume crops may be found in the *Alberta Forage Manual*, Agdex 120/20-4, and in the *Varieties of Perennial Hay and Pasture Crops for Alberta* (Agdex 120/32) and for Saskatchewan *Forage Crop Recommendations* (ISSN 0383-3356).

Miscellaneous silage crops

Almost any crop can be ensiled for livestock feed if it is palatable and contains enough nutrients and moisture to be properly ensiled. Hail damaged crops or crops that are too weedy and not economic to spray can be ensiled. Some crops which are not common can be used for silage as well.

Hail damaged cereal crops should be treated in the same way as cereals grown for silage. If the crop is hail damaged before the hard dough stage and has adequate moisture (60-70 per cent) to pack and ensile properly, the crop will make silage. If the hail damage is severe, the quality of the silage will be reduced as there will be fewer heads and leaves in comparison to stems, which are high in fibre and low in protein. Nitrates may also be a problem if the crop is made into silage after the hail damage.

Weedy crops may also be ensiled to produce feed which is comparable to traditional crops.

TABLE 4. NUTRITIVE VALUE OF WEEDS VS. ALFALFA

	% Protein	Digestible Energy*
alfalfa	17.6	2.54
lamb's quarters	17.0	2.26
flixweed	15.6	2.17
kochia	15.4	1.76
stinkweed	15.2	1.86
wild oats	12.2	2.92

* mcal/kg dry matter

Precautions must be taken when using weeds for silage. Some weeds may not be palatable, may taint milk in dairy cows, or may be low in minerals. However, harvested in the green stage, most weeds make acceptable silage for livestock.

Kochia is classed as a weed and as a crop. It has been traditionally classed as a weed because once established, it is very difficult to control and it is a very aggressive plant. It has advantages as a crop since it grows very well in saline soils and can yield in excess of 4 tons/acre (9 tonne/ha) of dry matter. Feed quality is good, with crude protein ranging from 13-18 per cent, although the available calcium and phosphorous are not adequate to supply the needs of livestock. When feeding kochia, livestock should have access to an ample water supply since kochia grown on saline soils is very high in salts. These salt levels may be high enough to cause scouring in livestock.

Forage brassica crops such as kale and forage rapes may be used for silage. These crops are generally very high in moisture (85-90 per cent) and it is impractical to wilt them down to 65 per cent moisture. Effluent losses will be very high unless dry matter is added to absorb this excess moisture. Chopped hay or straw can be added, with limited success, but dry barley is best. There still may be seepage and packing problems.

Forage brassicas have a dry matter crude protein of approximately 16 per cent and a digestibility of approximately 68 per cent (similar to corn silage). Yields are 3-5 tons/acre (6.7-11.2 tonne/ha) of dry matter. Forage rape silage is not very palatable and it may require a few days for livestock to become accustomed to it, after which it is readily eaten. A diet consisting of only forage brassicas fed fresh to livestock can cause haemolytic anaemia and goitre caused by an amino acid compound S-Methylcysteine Sulphoxide (SMCO). If forage brassicas are ensiled, this toxic factor is eliminated.

Forage brassicas are late maturing and may not be ready to harvest for silage until September to mid October, but they tolerate frost well (up to -5°C).

Only a limited number of varieties of forage brassicas is available for forage production in Canada.

Canola can be used as a silage crop, although it is generally only used when it has been frozen or is too weedy to produce good seed yields. Agriculture Canada at Melfort silaged frozen canola and found that the crude protein was 16%. When fed to calves, gains were less than half that of calves using brome-alfalfa for a roughage. Canola is low in palatability and as it matures it becomes coarse and stemmy. Frozen canola should always be tested for nitrates.

THE ENSILING PROCESS

Silage is the feedstuff resulting from the preservation of green forage crops by acidification. Acidification is the result of the fermentation of the forage in the absence of oxygen.

There are two main phases in the ensiling process. The first is the aerobic phase which occurs in the presence of oxygen (air). Oxygen is present in the forage as it is placed in the silo. This oxygen is consumed by the living plant material through the process of respiration. Under aerobic conditions plant enzymes and microorganisms consume oxygen and burn up the plant water-soluble carbohydrates (sugars) producing carbon dioxide and heat. The length of this phase is variable depending on ensiling conditions; it could last for a few hours or for as long as several days. It is good silage making practice to limit this phase as much as possible since water-soluble carbohydrates are being consumed and other nutrients are being destroyed. The heat generated by an extended aerobic phase can raise the temperature of the ensiling forage material sufficiently to cause heat damage. Good silage making practices reduce the amount of time that aerobic microorganisms and oxidizing plant enzymes are able to function. This is accomplished by chopping the silage to a short length, packing it thoroughly, and sealing the silo effectively.

The second or anaerobic phase begins when the available oxygen is used up through plant respiration and aerobic bacteria cease to function. Anaerobic bacteria (bacteria that grow in the absence of oxygen) then begin to multiply rapidly and the fermentation process begins. Ideally the microorganisms which grow most rapidly will be predominately lactobacilli species which produce lactic acid from the fermented plant material. The lactic acid which is produced will lower the pH of the silage. Fermentation completely ceases after 3 to 4 weeks when the pH becomes so low that all microbial growth is inhibited.

If ensiling procedures are such that lactic acid producing bacteria aren't favored, clostridial type microorganisms will grow. These organisms utilize plant water-soluble carbohydrates, lactic acid and protein for growth and produce butyric acid. The quality of silage is greatly reduced if a clostridial type of fermentation predominates.

The foregoing is a very simplistic summary of the ensiling process. In addition to lactobacilli and clostridial microorganisms, silage also contains yeasts, molds, coliforms, bacilli and propionic acid producing bacteria. In addition to utilization of plant sugars as energy sources, silage microorganisms degrade protein to amino acids, amines and ammonia during fermentation. Literally hundreds of fermentation products are formed in addition to lactic and butyric acids.

Factors affecting silage fermentation

The primary factors affecting the success of silage fermentation are:

- water-soluble carbohydrate content
- buffering capacity of the forage
- moisture content of the forage
- type of bacteria which predominate
- speed of fermentation.

These factors are interrelated and can be affected by management of the silage making process.

Water-soluble carbohydrates

Microorganisms use *water-soluble carbohydrates* (WSC) as the main energy source for growth. The main sugars present in plants are fructose, glucose, sucrose, and fructosans. There is only limited fermentation of other carbohydrates in plants such as starch, cellulose and hemicellulose.

Under some conditions fermentation may be limited by a low WSC content of the forages. Under these conditions the pH is not lowered enough to achieve safe preservation. Normally a minimum of 6 to 12 per cent WSC are required for proper silage fermentation. It is therefore important to understand the factors which will influence the WSC content of forages.

TABLE 5. WATER SOLUBLE CARBOHYDRATE LEVELS IN DRY MATTER OF DIFFERENT CROPS

Forage	% Water soluble carbohydrates
Alfalfa	
Vegetative	9
Early bloom	7
Full bloom	7
Clovers	
Cut 1	9
Cut 2	5
Grasses	8-25
Timothy	10
Orchard grass	6
Quack grass	13
Brome grass	9
Reed canary grass	7
Legume grass mixtures (50:50)	13
Corn silage	
Early harvested	31
Medium	14
Late harvest	8
Barley	
Heading completed	17
Flowering	18
Milk stage	32
Soft dough stage	24
Ripe	5
Sunflowers	
Flowering	19
Seed stage	19
Dough stage	12

Examples of water soluble carbohydrates in experimental forage. Adapted from information in McDonald, P. 1981. *The Biochemistry of Silage*. John Wiley & Sons, Toronto and Smith, D. 1973. *The nonstructural carbohydrates*. Page 105. In *Chemistry and Biochemistry of Herbage*. G.W. Butler and R.W. Bailey, Ed. Vol. 1. Academic Press, New York.

1. *Type of plant:* Legumes, in particular contain low amounts of WSC (table 5) and this is one reason why they are quite difficult to ensile. There are differences between grass species in the amount of sugars which they contain, with timothy and orchardgrass having a lower amount than other grasses. Forage corn contains enough WSC to ensure successful ensiling and barley forage contains adequate amounts for preservation at the mature stage when silage is normally made.
2. *Stage of growth:* The WSC content of perennial grasses increases as the plants mature. In whole plant barley forage WSC increase until about the milk stage.

3. *Growing conditions:* Plants contain much greater amounts of WSC when growing conditions have been cool with plenty of sunshine. Heavy rainfall during growth can reduce WSC up to 50 per cent.
4. *Management conditions:* There is a decrease of WSC during wilting. If wilting takes longer than normal, this reduction in sugars can have a very detrimental effect on the ensiling process.
5. *Drought:* Drought will reduce the WSC content of forages.
6. *Daily variations:* Total WSC concentrations appear to increase in the morning and start to decrease in the afternoon.
7. *Fertilization:* High rates of nitrogen fertilizer can influence the nitrate concentrations in forages. High nitrate levels which are undesirable in the ensiling process are generally associated with lower levels of WSC. Some of the nitrates in forage are ultimately degraded to ammonia which tends to raise the pH of the silage.
8. *Planting density:* WSC decrease if plant densities are high.

Buffering capacity

The *buffering capacity* of forages has an influence on the ease with which the forage can be ensiled. Buffering capacity of forages can be defined as the degree to which forage material resists changes in pH. Forages with a high buffering capacity will be highly resistant to a reduction in pH which is necessary for good preservation. Therefore more acid must be produced to reduce the pH to desired levels. This is undesirable in silage because more WSC must be used to produce the additional acid. Where the buffering capacity is high, it has been estimated that twice the amount of WSC is required to give good fermentation, compared with forages with a low buffering capacity.

The organic acids (malic, succinic, malonic and glyceric acid) in forages are mainly responsible for buffering capacity. In the ensiling process these organic acids are degraded by bacteria and are replaced by acids with stronger buffering properties. These replacement acids cause the buffering capacity of the forage to increase two to fourfold. Plant proteins also increase the buffering capacity of silage.

Legumes are generally well buffered (table 6) which means that more acid is required to cause changes in the pH of the fermenting material. As a general rule about 10-12 per cent WSC in legume dry matter will be sufficient for ensiling to occur whereas with grasses a minimum of only 6-8 per cent is required. Beet pulp, which has a low buffering capacity, only requires about 4-6 per cent WSC for good preservation. As can be seen from table 5, legumes often contain less than the minimum amount of WSC allowing an undesirable type of fermentation to occur.

TABLE 6. BUFFERING CAPACITIES OF FORAGES¹

Crop	Buffering capacity ²
Forage corn	200
Orchard grass	300
Ryegrass	250-400
Alfalfa	400-600
Clover	500-600

1 Adapted from McDonald, Volume 3, P. 1973. The ensilage process. Page 33. In Chemistry and Biochemistry of Herbages. G.W. Butler and R.W. Bailey, Ed. Academic Press, New York and other sources.

2 Buffering capacity is expressed as milliequivalents of NaOH required to change the pH from 4.0 to 6.0 in 1 kg of forage dry matter.

Environmental conditions also influence the buffering capacity of forages. First cut alfalfa has more buffering capacity than second or third-cut alfalfa, whereas the reverse is true for some grasses. The buffering capacity of ryegrass has been shown to decrease with maturity.

Moisture content

In general, the lower the moisture content in the crop, the higher will be the pH at which anaerobic stability is reached (table 7). Organic acids are lost in the wilting process and this reduces the buffering capacity of the plants which improves the ensiling process. This factor is one of the reasons why field wilting is beneficial with crops which have low WSC contents and high buffering capacities.

Another aspect which makes wilting beneficial for ensiling is that lactic acid bacteria are more tolerant to lower moisture concentrations than are the undesirable clostridial organisms. Very wet forage (greater than 70 per cent water) is therefore undesirable since clostridial growth may not be inhibited even when the pH drops to 4. Also with wet forages, the nutritional value and voluntary intakes of the silage produced are often low.

Wilting is usually restricted to perennial grasses and legume crops. Cereals usually have moisture levels suitable for rapid ensiling.

TABLE 7. EFFECTS OF WILTING ON THE COMPOSITION OF GRASS SILAGE

	Unwilted	Wilted
pH	4.0	5.1
Dry matter (%)	15.8	35.0
Lactic acid (%)	16.5	3.4
Acetic acid (% of DM)	1.9	0.6
Butyric acid (% of DM)	0.5	0.1
Ammonia N (% of total N)	10.9	8.0
Water-soluble carbohydrates	1.1	18.5

From Morgan, Edwards and McDonald. 1980. J. Agric. Sci. Camb. 94:287

Several methods are commonly used to estimate moisture content of forages prior to being placed in the silo. Several different types of moisture testers are commercially available. The hand or squeeze method of estimating moisture content in chopped forage is described in table 11 in the section on silage harvesting. Microwave ovens can be used to analyse a forage sample for moisture content. The method is described in table 12 in the section on forage harvesting.

Type of bacteria which predominate

The most desirable fermentation will occur where lactic acid producing bacteria predominate. Although it is frequently assumed that fresh forage is adequately supplied with lactic acid producing bacteria, the numbers may be low under some circumstances. Many of the silage inoculants on the market are formulated to increase the numbers of these bacteria.

Following good silage making procedures will facilitate development of anaerobic conditions that will aid in the rapid growth of lactobacilli in the silage.

Speed of fermentation

Since the primary aim of storing forages as silage is to preserve the material with a minimum of nutrient loss, it is desirable to limit the nutrient consuming activity of aerobic micro-organisms and to inhibit the breakdown of protein by clostridia micro-organisms under anaerobic conditions.

The preceding discussion has covered the main factors influencing how rapidly fermentation will progress. Managing silage making to ensure rapid fermentation will help minimize nutrient loss during the ensiling process.

Characteristics of good ensiling procedures

Exclusion of air

It is extremely important that air be excluded to optimize fermentation. There are several reasons for this:

- Plant respiration results in the loss of nutrients which would otherwise be available for the anaerobic bacteria to use for lactic acid production.
- Temperature of the ensiling forage will increase when oxygen is present. This is generally undesirable since high temperatures lead to heat damage of the silage.
- Air in the silo delays the breakdown of the plant cells and the release of plant juices. This in turn delays the onset of rapid fermentation since the nutrients in the juices are not immediately available to the microorganisms.
- Exposure to excessive oxygen during silo filling encourages growth of fungi which cause greater instability and susceptibility to aerobic deterioration when silage is being fed.

All of these factors tend to delay the development of the lactic acid producing bacteria, encourages the proliferation of undesirable clostridia bacteria, and promotes protein breakdown.

The actual amount of atmospheric oxygen which is initially trapped in the forage is very small. Measurements have shown that if sealing is adequate, 99.5 per cent of the oxygen can be used up in 30 minutes by respiring plant tissues. This amount of combustion causes very little temperature rise (less than 3°C). However, considerable air can enter the forage if silage is not covered with plastic or sealed in some other manner. Slow silo filling, forage that is not chopped finely enough, and inadequate packing are other causes of excessive air in silage.

Low temperature

When microbial growth occurs in silage, there is a rise in temperature. In general, the greater the growth rate of micro-organisms, the higher the temperature. It is known that the rate of acidification is greater when silage temperatures are higher and that the onset of fermentation is earlier. As a result, people have incorrectly concluded that hot silage is good silage. Higher temperatures encourage the growth of undesirable clostridia which result in increased butyric acid and ammonia formation which is detrimental to quality. Temperatures in the 15 to 25°C range have been shown to allow growth of the more important lactic acid producing species of bacteria while inhibiting the undesirable clostridial species. Silage temperatures should thus not exceed 30°C.

High temperatures will cause heat damage in silage. When the temperature of the silage exceeds 40°C in the presence of oxygen, a chemical reaction between plant WSC and protein occurs. This reaction produces brown products which give heat damaged silage its characteristic brown color with a tobacco or caramelized odor. The protein that is bound in this 'browning reaction' is largely indigestible to the rumen micro-organisms and to the animal. As can be seen in table 8, the higher the temperature in the silage, the greater the reduction

in protein digestibility. Fresh forage protein typically has a true digestibility of approximately 90 per cent, regardless of the forage source. Excessive heating can reduce this digestibility to 30 per cent or less. It should also be noted that the longer the time that the high temperature persists, the greater will be the damage to the forage.

TABLE 8. PROTEIN DIGESTIBILITY (%) AS AFFECTED BY TEMPERATURE AND LENGTH OF STORAGE

Heating period (days)	43°C (110°F)	57°C (135°F)	71°C (160°F)
0	69.7	69.7	69.7
3	68.7	65.8	60.2
9	68.4	64.4	50.0
18	65.2	58.6	35.8
30	65.4	49.0	30.1

From Gallagher, D. W. and K. R. Stevenson, 1976. Heat Damage in Hay-Crop Silage. Ontario Ministry of Agriculture and Food. Factsheet No. 76-007.

Routine feed analysis does not detect heat damage. A special analysis to determine acid detergent insoluble nitrogen, more commonly referred to as ADIN, is required to determine the extent of heat damage to forages.

A limited amount of heat damage in silage may be beneficial in that heating produces protein that is resistant to digestion in the rumen but can be digested in the small intestine. This "bypass or escape protein" often results in improved performance of the animal, particularly those at high production levels. Controlled application of heat to produce bypass protein in some feed ingredients is used by the feed industry. However, this requires good control of temperature and duration of heating to be successful. In practice there is little control of either in silage making, therefore excessive heating in the silo should be avoided.

Rapid acidification

Since it is ultimately the pH of the silage which stops the fermentation, pH is of great importance. It is the rate of acidification rather than the ultimate pH achieved that is of the greatest importance, since rapid acidification reduces the risk of early growth of clostridial organisms. In direct cut, high moisture situations, ensiling procedures should be such that rapid acidification is achieved. However, with high dry matter crops and if sterilants have been used, the rapid decrease in pH is not so important.

Methods of controlling the ensiling process

Moisture content

This is the most important means of controlling the ensiling process. Wilting in the field is the practical way to obtain the correct moisture for ensiling. A desirable moisture level is 65 per cent, but slightly higher moistures may be desirable when long chop lengths are used, when packing is minimal, or when the silage is not well sealed. Less moisture (40 to 50 per cent) is required in some oxygen limiting silos. The recommended moisture content of forage stored in different types of structures is given in table 9.

At moisture contents greater than 65 per cent, seepage and loss of nutrients will occur in tower silos more than 30 feet high. Such high moisture levels will also encourage growth of undesirable clostridial organisms.

At moisture levels lower than 60 per cent, excessive heating is likely to occur unless an oxygen limiting silo is used.

TABLE 9. SILO TYPE AND RECOMMENDED MOISTURE LEVELS

Silo type	Recommended moisture level %
Horizontal	60-70%
Concrete tower	60-65%
Oxygen limiting	40-50%
Silo bags (plastic tubes)	60-65%

Mechanical pretreatment

Chopping, cutting, and bruising all improve the potential for making good silage. This is due to cell breakage which favors bacterial growth and facilitates adequate packing for air exclusion. Anaerobic conditions can be established quickly in cut forage and thus temperature rise may be limited to 25 per cent of that observed in forages which have not been chopped (e.g., round bale silage). More lactic acid is formed and less dry matter losses occur when forage is chopped. The pH of the silage and its ammonia content that result from protein degradation are reduced, and lactic acid concentrations are increased with progressively shorter chop lengths. Where the length of cut has been reduced in silages an increased voluntary consumption by cattle has been observed.



Figure 16. Fine chopping improves packing and favors bacterial growth

Rapid filling, packing and sealing

Silos should be filled rapidly. The longer the time it takes to fill the silo, the greater the exposure of the silage to air will be.

Packing of silage is important to help exclude air from the silage in horizontal silos.



Figure 17. Packing of silage is important to help exclude air

Silage benefits from being sealed to exclude air. Generally, the sealing effect benefits only the surface layer of the silage, but if the silage is not well packed, it is beneficial for the entire silage mass. The silage making process can become anaerobic within 5 hours when the silage is sealed immediately after filling, whereas it can take up to 90 hours to become anaerobic when sealing is delayed for 48 hours. With alfalfa it has been shown that a delay of as little as 12 hours in sealing the silo caused a butyric acid type of fermentation to occur instead of the more desirable lactic acid type of fermentation.

Use of additives

The type and extent of fermentation which occurs in silage and the aerobic stability of the silage after it is removed from the silo can be controlled to some extent with silage additives. See the section on silage additives for more information.

Opening the silo

A *second aerobic phase* begins after the silo is opened and the silage is exposed to air. Aerobic micro-organisms that have remained dormant in the absence of oxygen start to grow and this causes a rise in temperature of the silage. Normally there is also some appearance of mold at this time. Silage may start to undergo aerobic deterioration within a few hours of exposure to air, but may also be stable for as long as a few days. Very high moisture silages with a high buffering capacity are most susceptible to aerobic deterioration because they are most likely to be contaminated by fungi. Also susceptible to aerobic deterioration are some silages in which fermentation has been limited with additives. Silages which are more resistant to aerobic deterioration at feeding are those in which the length of exposure to oxygen has been kept to a minimum by rapid filling and packing during the silage making.

SILAGE ADDITIVES

Silage additives are used to reduce dry matter losses and improve the fermentation in the silo, reduce deterioration after the silo has been opened and to improve the nutrient value of the silage.

Good silage can be made without additives or preservatives if proper ensiling techniques are used. Silage additives may have a place, however, where crops with high water content, low levels of water soluble carbohydrates or a high buffering capacity are ensiled, or when storage structures which are not well sealed are used. Also it may be more convenient to make nutrient additions at the time of ensiling rather than at the time of feeding.

If additives are being considered the potential user should first determine the economic feasibility of using the additives. The cost of the preservative should be compared to the

expected decrease in storage losses and improvements in feeding value of the resulting silage. For example, if it is known that a silage product will reduce storage losses by 5 per cent, reduce the risk involved with making the silage under adverse conditions and improve milk production by a significant amount, then an investment in the product equivalent to at least 5 per cent of the value of the forage ensiled is justified.

When making decisions on silage additives remember that limited testing has taken place with many of the commercial preservatives on the market. Buyers must often guess at the benefits and potential advantages of using a particular type of preservative under their circumstances. A good knowledge of the ensiling process and of the use of additives in general will help ensure that money is not wasted on products of limited value.

TABLE 10. TYPES OF SILAGE ADDITIVES¹

Fermentation inhibitors		Fermentation stimulants		Nutrients	Aerobic inhibitors
Acids	Others	Carbohydrates	Bacteria and enzymes		
Acrylic	Ammonium bisulfate	Glucose	<i>Aspergillus oryzae</i>	Ammonia	Propionic acid
Acetic	Carbon dioxide	Beet pulp	<i>Bacillus subtilis</i>	Beet pulp	Caproic acid
Benzoic	Carbon disulfide	Citrus	<i>Lactobacilli acidophilus</i>	Calcium	Sorbic acid
Citric	Formaldehyde	pulp	<i>Lactobacillus bulgaricus</i>	carbonate	Pimaricin
Formic	Hexamine	Molasses	<i>Lactobacillus plantarum</i>	Citrus pulp	Ammonia
Glycollic	Paraformaldehyde	Sugar	<i>Streptococcus brevis</i>	Grains	
Hydrochloric	Sodium nitrate	Whey	<i>Streptococcus faecalis</i>	Minerals	
Lactic	Sulfur dioxide		<i>Streptococcus cremoris</i>	Molasses	
Phosphoric	Sodium		<i>Streptococcus diacetylactis</i>	Potatoes	
Propionic	metabisulfite			Urea	
Sorbic	Sodium chloride		Enzymes	Whey	
Sulphamic	Sodium hydroxide		-amylases		
Sulfuric	Antibiotics		-cellulases		
	-Bacitracin				
	-Streptomycin				
	-Bronopol				

¹ Adapted from McDonald, P. 1981. The Biochemistry of Silage. John Wiley & Sons, Toronto. 226 pp. and Woolford, M. K. 1984. The Silage Fermentation. Marcel Dekker, Inc. New York. 350 pp.

Specific silage additives and preservatives

Fermentation inhibitors

Mineral acids

Hydrochloric and sulfuric acid are very effective in reducing pH of silage. However, they are not recommended because of difficulties of handling these corrosive acids, the need to neutralize the acid silage before feeding to avoid depressed performance, and the acidosis in animals which tends to occur when acid-treated silages are fed. Severe magnesium deficiency can also occur in animals.

Organic acids

Formic acid is available in solutions containing 80-85 per cent formic acid. Application rates are 2 to 4 litres/tonne (5 to 10 lb/ton) of fresh forage for grass silage and 5 to 6 litres/tonne (12 to 14 lb/ton) for legume silage. Formic acid additions increase lactic acid production and suppress clostridial fermentation by acidification of the forage. This acid does not suppress yeasts.

Formic acid treatment has been shown to reduce dry matter losses during ensiling by 2 to 8 per cent. It also reduces protein and amino acid breakdown which improves utiliza-

tion of protein in many feeding situations. It is particularly effective in improving animal performance with direct cut silage. The treatment is less useful on silages which have been wilted before ensiling.

The high cost of formic acid has limited its use in silage making.

Propionic acid has high anti-fungal properties and also reduces bacterial growth. Application rates of 2.5 to 5 kg/tonne (5 to 10 lb/ton) of fresh forage reduce ensiling losses and improve aerobic stability. It is not quite as effective as formic acid and is more costly. It may be practical in situations where aerobic stability is important such as with dry silages.

Acetic acid application rates of 3 to 4 litres/tonne (2.7 to 3.6 litres/ton) of fresh forage or more inhibit clostridial organisms and yeasts. It also increases the aerobic stability of silage upon exposure to air. Compared with formic acid it is less effective and more costly.

Acrylic acid has potential as a silage preservative. When added to forage at about 2.5 kg/tonne (5 lb/ton) of fresh forage it restricts protein breakdown, reduces fermentation of plant water soluble carbohydrates, and improves aerobic stability. The sodium salt, sodium acrylate, is easier to handle than the free acid.

Benzoic acid has antimicrobial properties and is used in human food preservation. Its high cost precludes its use in silage preservatives at high levels.

Sorbic acid is widely used in the food industry as a preservative. At concentrations of 3 kg/tonne (6 lb/ton) of forage, potassium sorbate inhibits clostridial organisms, yeasts and molds. It is a comparatively expensive additive. Further experimentation is necessary for it to be recommended for silage but it may be useful in inhibiting spoilage after removing material from the silo.

Non-acid fermentation inhibitors

Formaldehyde is an inhibitor available as formalin which is 35-40 per cent formaldehyde gas and 10-15 per cent methanol in aqueous solution. It has strong antimicrobial properties and since it also stops protein breakdown it has been widely studied as a silage additive. Although this inhibitor is very effective, about 1 per cent of the formaldehyde is transferred into the milk of cows. It should not be used as a silage preservative.

Sulfur dioxide is a direct acting sterilant that decreases silage bacteria populations, increases the rate of acidification and decreases the breakdown of plant sugars. Application rates are about 3.5 kg/tonne (7 lb/ton). Sulfur dioxide is a liquid which becomes a gas when released from the application tank. As it is a hazardous chemical to work with it has little potential as a silage preservative.

Sodium metabisulfite is a solid chemical which contains 65-67 per cent by weight of sulfur dioxide and releases this sulfur dioxide when it comes in contact with water. The application of this preservative results in decreased sugar loss, decreased protein breakdown, and less dry matter loss during ensiling under some conditions. Levels of addition of sodium metabisulfite are in the range of 4-5 kg/tonne (8 to 10 lb/ton).

The product is most effective in wet silages (over 70% moisture) and may have a potential use with legume silages. The chemical is not effective when the temperature of the silage is greater than 30°C which is one reason it is not effective in dry silages.

Common salt (sodium chloride) has been considered as a silage preservative since it increases the osmotic pressure and therefore reduces the availability of water to micro-organisms. Research has shown that it has not improved the fermentation in silage and thus it is not recommended as a silage additive.

Antibiotics such as choromycetin, neomycin, penicillin, streptomycin, Aureomycin, Bronopol, Tylosin, and others have been evaluated as silage preservatives. In general they have not been found to be useful silage additives.

The antibiotic Pimaricin has no influence on the fermentation in the silage but at levels of 20 g/tonne (0.65 oz/ton) it substantially reduces losses in silage exposed to air.

Fermentation stimulants

Cellulolytic enzymes

These enzymes break down cellulose to glucose and thus provide bacteria with an energy source. In addition, digestion of the cell wall aids in the release of intracellular contents. The amount of enzyme activity in the product is usually adjusted so rates of application are between 1 and 5 kg/tonne (2-9 lb/ton) of fresh forage.

The enzymes are most effective in the pH range of 4-6 and when moisture levels of 70 per cent or more are present. They are not useful in wilted silages. In experiments where digestibility of the silage has been determined in animals, cellulase enzymes have generally not been found to be beneficial. Cellulases are expensive and are not currently recommended as silage additives.

Amylolytic enzymes

These are enzymes which break down starch. Malt, which contains amylolytic enzymes, has improved silage quality when added with cereal grain at a ratio of at least 1 part of malt to 4 or 5 of grain. The enzyme amylase has also been used for this purpose but is relatively expensive.

Microbial inoculants

These are being widely used in silage additives. Since a rapid drop in pH is desired in the silage making process and there are often low numbers of lactobacilli on fresh plants, in some circumstances there is merit in inoculating the forage with lactobacilli to encourage the development of a vigorous lactobacilli population. Microbial inoculants will not be beneficial in the silage making process if there is already a large population of lactic acid bacteria on the forage, if the bacterial strains in the inoculum are not well suited to the forage or the ensiling conditions, or if the number of viable micro-organisms added is too low.

Bacteria desired in the ensiling process should be fast growing, produce only lactic acid as an end product of fermentation, be acid tolerant, work at temperatures up to 50°C, grow in low moisture situations and should not degrade organic acids. Examples of suitable bacteria are: *Lactobacillus plantarum*, *Streptococcus faecalis*, and *Lactobacillus acidophilus*.

The products are generally most useful with crops low in sugars and difficult to ensile, such as red clover. In some instances it has been found useful to use a combination of sugars and microbial inoculants in the ensiling process.

Since the cost of microbial inoculants is quite low and application rates are only in the range of 0.05 to 1 per cent (depending upon the dilution of the inoculant) of the fresh forage weight, these products can be considered as an economical aid to controlling fermentation. Considerable research is being carried out with microbial inoculants and the products may have an increasing use in the future. At present there is not enough information to make blanket recommendations concerning the economics of using inoculants. There are considerable differences between products, however, so it is advisable to obtain more information before inoculants are used.

Molasses and sugars

Molasses and sugars such as sucrose have been widely used as silage additives. Molasses, in particular, is a potentially economical preservative and should be considered when wet legumes are ensiled. Molasses contains about 50 per cent sugar by weight and is normally added to silage at a rate of 20-50 kg/tonne (40-100 lb/ton) of forage. The higher levels are recommended with wetter, immature forages and for legumes. Molasses is often diluted with an equal weight of water before use but this has the disadvantage of adding more water to silage.

Molasses additions to forage provide micro-organisms with additional available sugars, which results in more rapid growth of lactic acid bacteria and a reduction in clostridial organisms.

Aerobic inhibitors

Substantial spoilage occurs when silage is exposed to air for periods of 12 hours or longer after being removed from a silo. Additives that improve aerobic stability include propionic acid, acrylic acid, sorbic acid, some antibiotics and some microbial inoculants. Ammonia and urea additives improve aerobic stability as well as add crude protein to the silage. These compounds are discussed in other sections.

Nutrient additives

Cereal grains

The cereal grains (barley, corn, oats, rye, triticale and wheat) have been ground and added to forage to supposedly add available nutrients for micro-organisms. Starch, however, is relatively resistant to attack by lactobacilli, thus their growth will not be improved much with ground grain additions. Many endospore-forming bacteria such as clostridia can break starch down, thus grain additions may actually increase the number of spoilage organisms in silage.

In spite of these problems, ground grain has been added to silage and is useful in reducing the moisture content of very wet silage and in increasing the lactic acid content of silage in some circumstances. Usually the resulting silage is better than silage without additions since the unfermented grain is a good source of nutrients to the animal. Losses in feed value of the grain during ensiling can amount to 5-10 per cent, however, making this an inefficient way of adding supplement.

Liquid whey

Liquid whey is a very cheap feed and its disposal has been a problem. The product is high in lactose (about 4.4 per cent) and some, but not all, of the lactobacilli utilize lactose as a source of nutrients.

Liquid whey contains only about 6.6 per cent dry matter. This means that it will normally not be useful for ensiling high moisture silages. With mature cereal silages, however, it may be useful to add wet whey.

Dried whey can be added to silage at a level of about 4 per cent of the fresh forage weight but economically it is not as useful as molasses.

Urea

Urea can be added directly to the forage at the time of ensiling to increase the crude protein content of the forage. This practice may be of the most use with corn silage and some cereal silages. Usual levels of addition are 2.5 to 5 kg/tonne (5 to 10 lb/ton) of fresh forage. It has been shown that as much as 25-50 per cent of added nitrogen may be lost in the ensiling process.

Ammonia is released from urea during ensiling. This compound is a base and thus tends to neutralize some of the acid produced and prolong fermentation. As a result, there is a lower concentration of acids in silage treated with urea

than in untreated silage. Urea also increases the concentrations of crude protein, true protein, free amino acids and ammonia in silage. Urea nitrogen is incorporated into microbial protein in the ensiling process. The aerobic stability of silage treated with urea may be increased because a greater total fermentation occurs with a corresponding reduction in water-soluble carbohydrates.

In general animals favor silage treated with urea less than they do silage with a natural protein supplement. The major advantage of adding urea at the time of ensiling is that it can be well mixed with the forage and eliminates the need for adding a protein supplement at feeding time.

Ammonia

Ammonia applied to forage at the time of ensiling increases the crude protein content of the forage. Levels of addition of an aqueous ammonia solution which contains 25 per cent ammonia are 5-15 kg/tonne (10-30 lb/ton). Molasses may also be added with ammonia to increase the amount of sugars in the ensiling material.

Anhydrous ammonia (NH_3) is often added to forage at levels of 0.5 to 1% of the forage dry matter (2 to 4 kg/tonne of fresh forage). This is lower than the amounts which are used to treat straw or preserve high moisture hay. When liquid ammonia is released from a tank it expands, changes to a gas, and cools the surroundings. An application apparatus is available (Cold-flo™) which utilizes this principle to keep most of the ammonia cold enough to remain as a liquid until it contacts the forage, thus reducing losses.

Ammonia, like urea, also results in increases in the crude and true protein content of forages. Concentrations of organic acids are also increased. Generally there is also an increase in the aerobic stability of the forage.

The effect of ammoniation on the nutritive value of silage has been variable and primarily related to whether a protein deficiency existed in animals fed silages without ammonia supplementation. Ammonia additions are economical at the present time with cereal and corn silages but should not be considered with higher protein silages.

Mineral additives

Mineral additives such as ground limestone have been included in silage at levels of 0.1 to 0.3 per cent of the fresh forage to increase the calcium content of the silage. Crops ensiled with limestone have higher concentrations of organic acids and less water-soluble carbohydrates after ensiling since limestone is basic and neutralizes some of the acids produced during fermentation. This allows fermentation to proceed for a longer period of time. A butyric acid type of fermentation can be expected if low amounts of water-soluble carbohydrates are present when limestone is used. However, good silage can be made with limestone additions if enough water-soluble carbohydrates are present. Corn silage, in particular, is deficient in calcium and may benefit from ground limestone additions.

Magnesium compounds have been added to silage to increase the content of this element in silage and thus prevent magnesium deficiencies in cattle.

SILAGE HARVESTING

Understanding some of the basic requirements of an effective and efficient harvesting operation will assist in the production of good quality silage.

Variability in harvesting weather is a problem with any system. However, because it is less dependent on good weather and there are fewer harvesting losses involved, silage production is an attractive option compared with other forms of forage harvesting. The weather conditions that can be tolerated depend on the method of silage production and the moisture content at which the crop is harvested. Silage harvesting can be divided into three categories depending on the crop and the moisture content at which it is harvested, as follows.

Direct-cut silage

Direct-cut silage is made by cutting, chopping and immediately ensiling the crop. Most crops cut at the late bud to early heading stage will have a moisture content in excess of 70 per cent. This high level of moisture dilutes the acid concentration and results in poorly preserved silage. High levels of moisture can also result in considerable nutrient loss through seepage. Excessive moisture can cause silage to freeze during the winter months.

Direct cutting is best used when moisture content is approximately 65 per cent or lower (alfalfa in full bloom, grasses fully headed or cereals in the early to soft dough stage). Crop mixtures such as barley and peas, or barley and fababeans, can be direct-cut when the barley is quite mature. This reduces the average moisture content of the mixture.

Wilted silage

Wilted silage is made by allowing high moisture forage crops to dry in the windrow for several hours or until the moisture content is reduced to the correct level. For example, for conventional horizontal silos the moisture content should be 65 per cent. Wilted silage has the following advantages compared with silage which is more moist than ideal for a given system.

- preservation of silage is improved
- losses caused by seepage are eliminated when moisture content is decreased to less than 70 per cent
- freezing problems are substantially reduced
- dry matter intake of wilted silage by livestock is greater so animal production may be improved.



Figure 18. Wilting silage to 65-70% moisture content before cutting improves preservation

When making wilted silage the forage harvester should be set for a shorter cut to permit better packing. The exact setting needed relates to the percentage moisture and theoretical cut versus actual cut. An actual cut of about 0.5 inches or 12 mm is common.

Low moisture silage

Low moisture silage is made by allowing the crop to dry in the windrow until the moisture content is approximately 40 to 55 per cent. Although leaf losses and the risks of field weathering are increased, there are lower storage and freezing losses with well made low moisture silage. The main concern in making low moisture silage is excluding as much air as possible. Unless oxygen-limiting structures are used, a problem with high temperatures and mold growth during the ensiling process may occur because of air penetration. Thus, it is very important that the forage be finely chopped to about 0.25 in. (6 mm) actual cut, and be very well packed. Low moisture silage is generally not recommended for horizontal structures.

Harvesting systems

Once a particular method of silage harvesting is decided upon, the type and size of machinery used must be calculated. A harvesting system with components of matched capacity is vital to the silage making process. To maintain high quality forage and good silage preservation, the harvesting process should be completed as quickly as possible. Delays and stoppages can cause overdrying and quality loss. Equipment should be kept in good working order. Comparative information on the equipment outlined in this section can be obtained from the Prairie Agricultural Machinery Institutes which have offices in Lethbridge, Humboldt and Portage La Prairie. These are also available from district agriculturists and agricultural representatives.

Silage harvesting systems generally include a windrower, a harvester, and trucks or wagons to transport material to the storage site. The type of storage and the distance involved will often dictate whether trucks or wagons are used. Self-unloading wagons are convenient but have a hauling capacity which is limiting when long distances are involved. When hauling distances are greater than about 1 mile (1.6 km) a high dump wagon with trucks to haul is more efficient.

In Alberta and Saskatchewan, most crops to be ensiled, except corn, are windrowed in order to wilt the crop so it can be ensiled at the optimum stage of maturity and the proper moisture content. Corn silage is generally cut and chopped in one operation.

Crop maturity

One of the main advantages of producing silage is that timely harvesting is usually possible. The time to harvest will depend upon the crop and its stage of maturity (see Crops for Silage, page 2 for more information).

Since the speed of harvest is limited by manpower and machinery, it is difficult to harvest large acreages of an entire crop at the optimum stage of maturity. Experienced silage makers know the average daily production of their machinery and crew, and start harvesting before the optimal stage of maturity to avoid overly mature material. Planting crops or varieties which mature at different times increases the number of days at which the total crop is at optimum maturity.

Moisture content

The moisture content required for silage varies depending on the system used (see section on Silos p 25 for more information). Since the moisture content of forage fluctuates from day to day or within any one day, it is difficult to keep within the ideal range. In practice, the moisture content of individual cuttings may be on either side of the range as long as the final moisture content is within the range.

The recommended moisture content for silage in conventional horizontal silos is 60 to 70 per cent. Harvesting should begin when the forage reaches 70 per cent moisture. Try to harvest at moistures above 65 per cent to reduce field losses and to reduce the possibility of overheating caused by inadequate air exclusion. Corn silage should be harvested at 62 to 70 per cent moisture with the ideal being 65 to 68 per cent. When large acreages are involved, some corn can be harvested at over 70 per cent moisture.

The forage windrower (swather) should not get too far ahead of the harvester to avoid large quantities of forage becoming overdried. If some crop gets too dry, some high moisture silage, 70 per cent or over, should be placed on top of it in the silo. Seepage should then raise the moisture content of the overdried forage.

Several methods are commonly used to estimate the moisture content of forages prior to being placed in the silo. The hand or squeeze method of estimating moisture content in chopped forage is shown in table 11. Microwave ovens can be used to analyse a forage sample for moisture content. The microwave oven method is described in table 12.

TABLE 11. HAND METHOD FOR ESTIMATING THE MOISTURE CONTENT OF FORAGE AND SILAGE

Forage or silage squeezed in hand	Moisture (%)
Water easily squeezed out and material holds shape	More than 80
Water can just be squeezed out and material holds shape	75-80
Little or no water can be squeezed out but material holds shape	70-75
No water can be squeezed out and material falls apart slowly	60-70
No water can be squeezed out and material falls apart rapidly	less than 60

TABLE 12. MICROWAVE OVEN METHOD FOR DETERMINING MOISTURE CONTENT OF FORAGES

1. Weigh out approximately 100 g sample of the chopped forage (W1) excluding the weight of the container. Weigh to the nearest gram.
2. spread the weighed forage sample on a paper plate or place it in a paper bag and put it in the microwave oven.
3. Place an 8 oz glass three-quarters full of water in the oven to prevent igniting the sample.
4. Heat at 80 per cent to 90 per cent of maximum power for 4 minutes.
5. Remove the sample, mix it and weigh it.
6. Continue to reheat for 2 minute intervals, re-weighing each time. To prevent burning use lower heat and 30 second time intervals as it approaches being dry. If the weight of the sample does not change after two or three drying intervals, it is 100 per cent dry. This is the final dry weight (W2). A slightly charred sample should not affect accuracy of the moisture determination but if the sample burns the test should be repeated.
7. Calculate moisture content as follows:

$$\text{Moisture content} = \frac{(W1 - W2)}{(W1)} \times 100$$

Example - 64% = $\frac{100 - 36}{100} \times 100$

The microwave oven method is quick and precise but not always practical. Often it is desirable to know the moisture content as conditions change throughout the day. A reliable moisture tester is a useful tool. Several portable testers are available commercially and can provide reliable results. Calibrate and compare portable tester results with the results from the microwave oven method, to provide a check on meter accuracy. The Prairie Agricultural Machinery Institute (PAMI) tests and reports on various moisture meters. This information can be obtained from PAMI or your local agricultural extension office.

Windrowers

Proper swathing and a uniform windrow with most of the stems placed parallel to the direction of travel are essential to obtaining a short uniform length of cut with the harvester. Poorly windrowed fields with piled and tangled swaths result in a great variability in the length of cut of the silage.

Direction of travel is important in lodged or leaning grain crops. Cutting in the direction of crop lean generally results in parallel windrows while cutting at an angle to the direction of lean generally results in angled parallel windrows. To provide uniform swaths in grain crops, the reel should contact the stalks below the head. In light grain and forage crops the reel should be operated near the cutter bar to reduce bunching.

In tangled and lodged crops the use of a pick-up reel can reduce losses. An experienced operator is required to adjust travel speed, reel speed and reel raker finger angle to suit specific crop conditions. Lodged fields often contain areas of standing and semi-lodged areas. In such areas, the reel can become entangled with standing crop while trying to cut the lodged portion. The addition of a push bar in front of the reel can reduce reel tangling. In semi-lodged areas, the push bar bends the standing crop and allows the reel to contact the lodged portion. A push bar reduces losses in semi-lodged areas but produces a tangled windrow. Considerable operator care, experience and patience are required to effectively windrow lodged crops.

The use of mower conditioners increases the drying rate and results in more uniform drying. The use of a conditioner will likely permit harvesting two to six hours earlier, although much variation can be expected owing to weather conditions. Conditioned windrows tend to be fluffy with the stems lying in all directions. This increases the variability in the length of cut and reduces the silage density so that extra packing may be required to ensure safe storage. Mower conditioners are therefore not recommended in cereal crops. They can be useful when cutting legume crops especially in moist areas.

Harvesters

Most forage harvesters can be adapted to harvesting different types of crops. Pickups are available for windrowed crops, cutting heads for direct cut silage, row crop heads for whole plant harvesting and some can use ear corn snapping heads to make ear corn silage. Most harvesters use either a cut-and-blow or a cut-and-throw system of harvesting. The crop is delivered to the cutter head where it is chopped. Cut-and-throw harvesters deliver material directly to the wagon or truck. Cut-and-blow harvesters use a separate blower behind or beside the cutterhead to deliver the crop to the wagon or truck. Either type of harvester is capable of providing uniformly cut material.

A forage harvester should provide a uniform length of cut

with smooth, squarely cut ends while maintaining maximum efficiency. Most harvesting machines are capable of doing a good job provided the knives are sharp and proper knife clearances maintained. Proper preparation, plus careful maintenance and correct operation of the harvester help make the job go smoother and faster. Operator care and attention are a must.

The optimum length of cut for silage depends on the type of crop and moisture content. As a general rule, the drier the material the shorter the length of cut has to be. Dry forage is more difficult to pack and must be finely chopped. Finely chopped forage is easier to remove from silos and handles well in mechanical equipment. The performance of some silage unloading equipment may be adversely affected if a significant amount of the material is longer than 1.5 in. (38 mm). Cutting the material any finer than necessary for proper storage or feeding, however, wastes time and power.

For most crops, average actual length of cut should be about 0.5 in. (12 mm). Corn silage should usually be 0.25 to 0.5 in. (5 to 12 mm) long for best packing and fermentation.

For each length of cut setting, a forage harvester produces a range of material lengths. The actual average length of cut should be close to the theoretical length of cut when the stems in the windrow are parallel to the direction of travel. If the range of cut lengths is greater than desired, a recutter screen may be used. A recutter screen reduces the percentage of longer particles and results in finer and more uniform cut lengths. Recutter screens increase the power requirements and decrease the capacity of the harvester, and are generally not required. Figure 19 shows material length distribution curves for various swath types and with a recutter. Tangled and bunched swaths produce forage with a wide range of material lengths. For most crops no more than 10 per cent of the forage should be in pieces longer than 1.5 in. (38 mm).

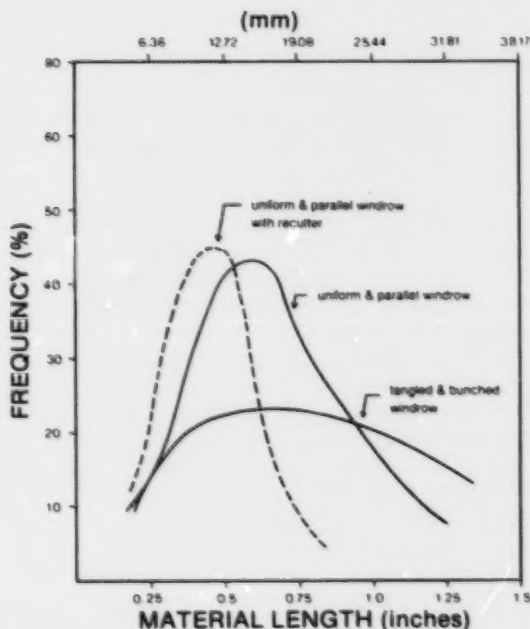


Figure 19. Material length distribution curves

The power requirements and work rates of forage harvesters depend on many factors. Power requirements increase for shorter lengths of cut. Actual harvesting rates depend on the particular harvesting system, tractor power, the size of the harvester and the field operating efficiency. Wagon unloading, headland turning and machinery maintenance times all affect harvest rates and vary with each system. Harvesting rates also vary with crop moisture content. With any system, harvesting rates are higher with heavy uniform windrows and moisture contents near 65 per cent. Often it is convenient to measure harvesting rates based on the crop dry matter weight. Dry matter harvesting rates consider the amount of dry matter harvested and are independent of crop moisture content. Dry matter harvesting rates allow for convenient comparison of harvesting rates of different crops at different moisture contents. Figure 20 shows average dry matter harvest rates that might be expected from a harvester operating at optimum levels for various cut length settings. The kind of crop also affects harvesting rate. Alfalfa generally requires more power than cereals or corn.

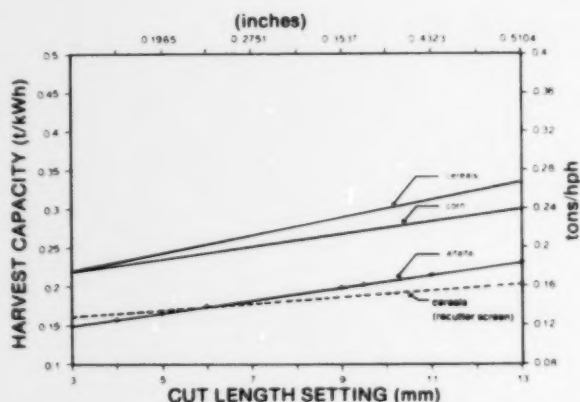


Figure 20. Harvesting rates for various crops at various cut length settings

Knife and shear plate condition and adjustment significantly affect power requirements, quality of cut and wear rate. Sharp knives and properly adjusted shear bar clearances (figure 21) increase knife and shear bar life, increase fuel efficiency and provide for the most uniform length of cut. A rule of thumb is to check and adjust the shear bar and knife clearance at least twice as often as the knives are sharpened. If a recutter is used, screen clearance must also be adjusted precisely and regularly.

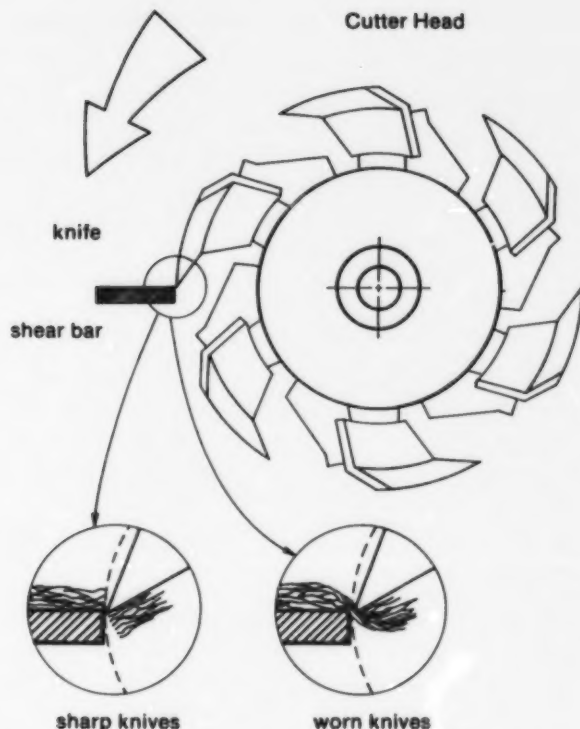


Figure 21. Forage harvester cutter knives should be adjusted properly

The amount of power available to the harvester is a major factor in determining the harvesting rate. For most crops and average field conditions, the tractor should be operated at about 80 per cent of its maximum rated power. This allows sufficient reserve capacity for hills and soft spots. Pulling a wagon or truck behind the harvester lowers the harvest rate by reducing the power available for cutting. A wagon full of silage in soft hilly conditions can require up to 25 hp (19 kw). A rough rule of thumb in sizing a forage harvester to a tractor is 8 hp per foot of swath: in alfalfa (20 kw/metre) or 54 hp (40 kw) per row of corn. It is best to match a harvester of high power rating with a similar sized tractor. An oversized harvester is a poor investment.

Wagons and trucks

Efficient transport of cut silage from the harvester to the storage site is a must. The most efficient system for each operation will vary depending on the amount of silage to be hauled, the distance involved and the type of storage used.

Tractor pulled self-unloading wagons are convenient for small operations with short hauling distances and upright silos. One tractor and operator can handle two forage wagons. One is hauled and unloaded while the other is being filled from the forage harvester. This system is satisfactory for short hauling distances (especially under one mile or 1.6 km). Self-unloading wagons are not as convenient in operations with horizontal silos, but can be used for feeding silage.

A popular means of harvesting silage is with a high dump wagon and using trucks for transporting to the silo. High dump wagons hydraulically raise and tip the silage box high enough to dump the load into an extended truck box. It requires two to four minutes to dump the load into a truck.

One truck can keep up to the system when the hauling distance is not over 2 miles (3.2 km). The high dump wagon can eliminate the need for one truck and one man depending on distances involved.

A high dump wagon requires an additional 20 hp (15 kw) to pull, under average conditions, and more with soft fields or hills. The wagons are quite stable if dumped on level



Figure 22. High dump wagons and trucks are an efficient means of transporting silage for short distances

ground. Trucks are faster than self-unloading wagons and are more suitable when hauling distances are over 1 mile (1.6 km). Trucks lend themselves well to operations with horizontal silos. Operations with upright silos require a blower feeding mechanism. Several types are available with varying unloading rates.

Arranging a well balanced harvesting system requires care and attention to equipment sizes and matching. The lowest capacity unit determines the harvesting rate of the whole system. Sufficient hauling and silo loading capacity should be obtained to keep the harvester working at full capacity. Typically, three to five people are required to maintain a smooth, continuous harvesting system. It is often convenient to share equipment and manpower among neighbors. This reduces individual capital requirements and can provide an adequate labor supply.

Harvesting system losses and efficiency

Dry matter field and hauling losses of 65 per cent moisture content forage can be kept to less than one per cent in a good harvesting operation, although losses of two per cent are common. Higher losses can occur with careless and inefficient operation of equipment. To maintain optimum efficiency use suitable equipment, take precautions to eliminate wind losses, and employ good operators who can maintain high field efficiencies. Follow the manufacturer's guidelines for proper operation, adjustment, and maintenance of all equipment to ensure rapid field harvesting and optimum silage condition.

SILOS

Silage making and storage

The storage system for silage is the most important part of the ensiling process. If the storage system does not perform properly, the quality of the silage fed will suffer.

There is no silage storage system that will guarantee success. Any system for making silage must be managed properly.

Silage quality varies a great deal. Very good feed may come from the simplest of silo storage facilities. Unfortunately, lesser quality sometimes results in spite of investment in very costly systems. Each manager must have a complete under-

standing of what is required for forage to ferment into silage. The manager must adapt those requirements to the silo type selected. Finally, if a dedication to making good silage is present the result will be excellent quality feed from whatever system is selected or designed.

Silage has the advantage of being harvested from the field at a high moisture content. This increases both the quality and quantity of feed taken from the field. Unlike baled hay, silage has a moisture content of 40 to 70 per cent. Forage will spoil at this moisture content unless it goes through the process of fermentation to become silage.

TABLE 13. AN EXAMPLE SHOWING ESTIMATED FEED LOSSES FROM VARIOUS SILAGE SYSTEMS UNDER GOOD CONDITIONS

Type of dry matter loss	Horizontal pit 65% M.C.	Horizontal concrete 65% M.C.	Concrete tower 65% M.C.	Oxygen limiting tower 45% M.C.	Silage Bags (tubes) 65%	Round bale silage 65%	Square bale hay (Sheltered) 20% M.C.	Round bale hay (Outside) 18% M.C.
Respiration and Weathering loss	4	4	4	6	4	4	10	12
Harvesting loss	2	2	2	3	2	4	3	5
Storage loss	15	12 (10-15)	9 (8-9)	5	7 (5-9)	18 (10-25)	3	6
Feeding loss	4	4	2	2	4	4	5	5
Total	25%	22%	17%	16%	17%	30%	21%	28%

Note - Losses are highly variable and can be much higher depending on management and climatic factors. Oxygen limiting towers and concrete towers are the least affected by these factors. Polyethylene deteriorates with time so that systems most dependent on it for excluding oxygen have greater losses with long-term storage. Research presently underway will provide additional information on feed losses of new silage-making methods including silage bags.

- Information was adapted from "A model for estimating silo losses and costs", McIsaac and Lovering, Canadian Farm Economics, Vol. 15, No. 5; Hoglund, C.R. 1964. Comparative losses and feeding values of alfalfa and corn silage crops when harvested at different moisture levels and stored in gastight and conventional tower silos, Mich. State Univ. Agr. Econ., Publ. 947; Silo types and their use, Agric. Can. Canadex 120.60, and Grass, legume and cereal silages for ruminants, Agric. Can. Publ. 1786E. and other sources.

The silo storage system serves one main purpose in this process. It helps remove and maintain the exclusion of air (see ensiling process p 14). In a tower silo, the weight of silage forces the air upward through the silage to the top. After the ensiling process starts, a layer of carbon dioxide (CO₂) lies on the silage surface excluding new air from the silage. Use life support breathing equipment to enter this environment. For a horizontal silo (trench, bunker, stack) the silage must be packed to exclude air. A heavy tractor driven over the surface forces the air from the silage. A layer of forage or a cover then prevents air from entering the silage. A silage tube packing machine acts to exclude the air as it stuffs the forage into a silage bag.

Forage losses

When selecting a forage system consider forage losses in the field, harvesting, and storage and feeding with various systems. Table 13 provides a summary of the average losses that are estimated to occur under various systems with good management practices. Much higher losses are possible if good production practices are not followed, e.g., mending tears in plastic covers, using concrete floors etc. See the section on economics for additional information comparing various systems.

Horizontal silos

There are two basic types of horizontal silos - below ground level (i.e., pit or trench types) and above ground (i.e., bunker and stack types). The main advantage of horizontal silos is that they are less costly to construct and are well suited to feeding livestock in widely separated pens.

Pit silo: This type of silo is dug into the ground on a level site. It requires a sump to collect drainage which must be pumped out to a suitable disposal location. This can be a problem, especially in spring or after heavy rain. Pit silos are not commonly used because of problems with drainage and high water tables.



Figure 23. Earth walls for trench silos should be sloped at a ratio of 1:2 to prevent caving in and to enable adequate silage packing

Trench silo: These commonly used silos are dug into a slope with the "downhill" end open for drainage and access. Earth walls should be sloped at a ratio of 1:2 to prevent caving in and to enable adequate silage packing. Where soil

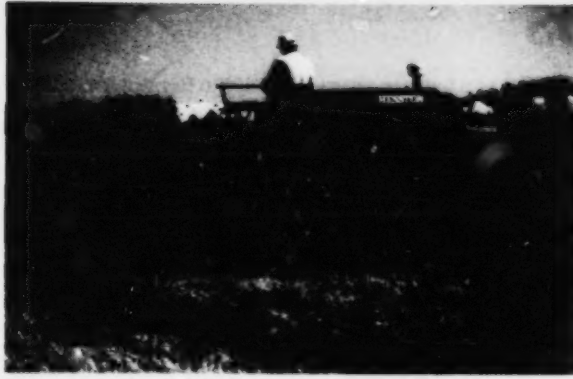


Figure 24. Field wilting is often required for legumes

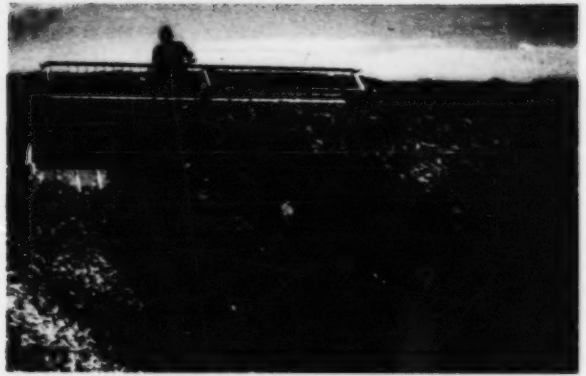


Figure 25. Sweet-clover is a popular silage crop in drier areas

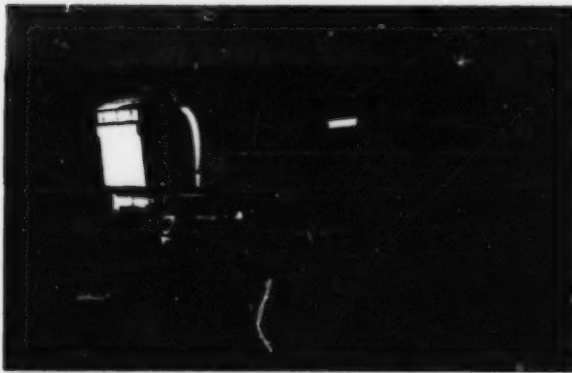


Figure 26. A silage dump wagon complements trucks for short hauling distances

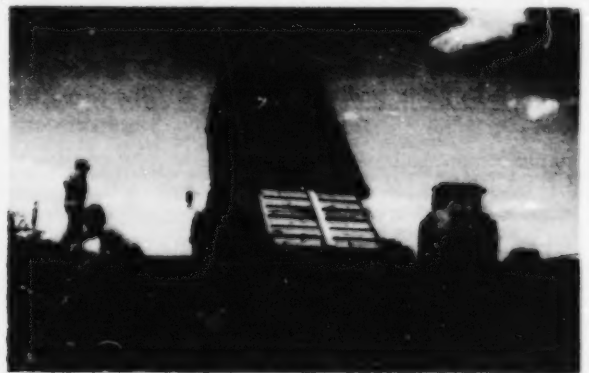


Figure 27. Trucks are efficient for transporting silage to the silo



Figure 28. Sloped walls permit packing to the edge of the silo



Figure 29. Bunker silos can provide efficient storage for large operations

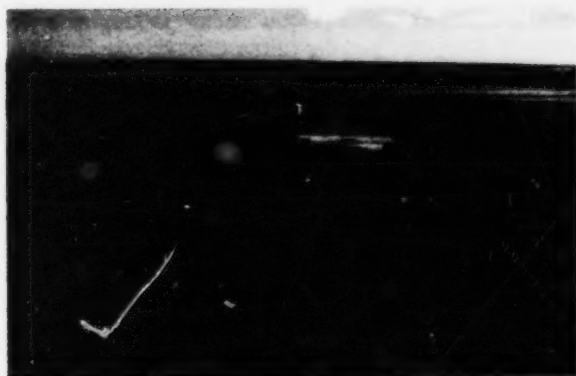


Figure 30. Visible tire tracks indicate effective packing



Figure 31. High silo walls and plastic cover minimize surface losses



Figure 32. Not covering the silo when filling is interrupted results in a spoiled layer

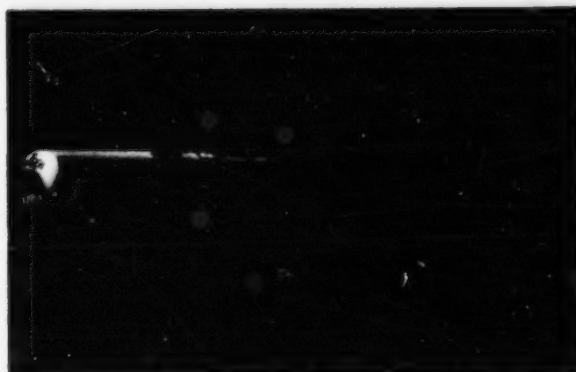


Figure 33. Adding anhydrous ammonia increases protein content of cereal silage

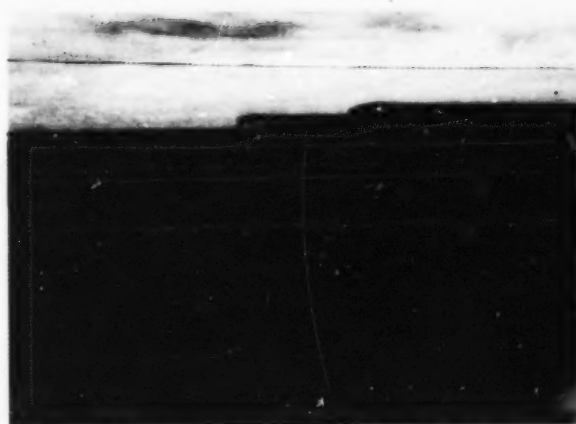


Figure 34. Feeding silage on a fence line concrete pad



Figure 35. A front end loader and feed tables are a low cost system for smaller herds

is unstable it is necessary to line the walls with concrete or untreated wood. A convenient width for loading with a tractor and front-end loader is 50 ft (15 m). A reinforced concrete floor will stand up under high moisture from silage, rainfall and spring thaw. The floor should be sloped at one to two per cent to the open end for adequate drainage. It is preferable to have the open end facing south. Special construction techniques are available for bunker soil walls and floors. See Alberta Agriculture Farm Building Plan Service, Agdex 713-1 and Canada Plan Service information.

Bunker silo: This type of silo is used in flat areas where a trench type cannot be located close enough to the feeding area. Above-ground walls are constructed using concrete, earth or wood (planks or lowest grade plywood) braced with timbers or concrete buttresses. The inside silo lining should not be treated since wood preservatives presently registered in Canada *cannot* be used in direct contact with livestock feed. Permanent wood lining or walls should be covered with plastic to prevent moisture and acid penetration. Walls, end posts and braces must be designed to withstand the pressure of the silage and the packing tractor. Bunker silos require adequate drainage. Concrete floors are usually needed for easier loading and to minimize feed waste. Where earth floors are used traffic must be limited (especially animal self feeding).



Figure 36. Bunker walls must be well braced

Silage stacks: Stacks are best used for storing an unexpected surplus of forage or as an interim method when first trying silage. Silage stacks must be located where drainage is good. Per cent spoilage is often high, since a stack has a large surface area exposed to oxygen and the weather. A sealed plastic cover is required. Where available, large round straw bales braced in place and lined with 6 mil plastic can be used as a temporary wall. The resulting silo would act like an above-grade bunker. The use of a large stack also minimizes the amount of surface spoilage. The most efficient shape is a

domed stack. This also permits tractor packing over the entire surface. The packing tractor must be operated very carefully. The width and length of the stack are also affected by the removal rate for feeding, i.e. remove about 4 in. (10 cm) average length per day.

A silage making system developed by Agriculture Canada in Kapuskasing, Ontario, called the KAP method involved forming a silage stack without packing it. This method is being tried on the prairies where it is also known as heap silage. It appears to be an effective low cost method for making small quantities of silage. Heap silage is useful for preserving unexpected surplus silage or for first time silage users who do not yet have a permanent silo.

In the heap silage method, cut forage is pushed into a 12 to 14 foot (3.5 to 4.3 m) high pile with a tractor and front loader without packing it. Immediately after piling, the stack must be hand groomed so that a single sheet of 8 mil silage grade plastic fits evenly over it. The plastic must be anchored so that it is held firmly against the pile as it settles. A good method is to suspend tires weighted with sand bags on ends of ropes going over the stack. The plastic cover must also be well sealed at ground level. Sand works well to make the seal and is not as easily washed away as soil, etc. If the plastic seal is good plant respiration will exclude oxygen from the pile within 24 hours.



Figure 37. For heap silage the plastic tarp must be well anchored to stay tight after the silage settles

Filling and packing horizontal silos

Filling of a horizontal silo starts at the end opposite the entrance with the pile sloping to the entrance. The cut forage is added to the sloping face in uniform layers. Keep the front slope as steep as the packing tractor can handle without spinning. The quicker that layers of silage can be added, the better. The layers are packed into place by a heavy tractor driven on the silage surface. A heavy tractor compresses the silage mass forcing the air out. Pack on deep layers of new silage (i.e., 2 ft or 60 cm). As much packing as possible should be done immediately. The packed surface should feel firm to walk on. If one sinks to the ankle or the step has a spongy bounce, more packing is needed. It is usually difficult to pack the top one or two feet of cereal silage adequately. The next load of silage added will seal air from the packed silage underneath. Once packed, the plant material and bacteria will use the remaining oxygen in the silage. Any additional packing would squeeze out the desirable carbon dioxide produced by fermentation and introduce unwanted new air. After a break in harvesting add new silage before packing.

If equipment can work from the walls (trenches or earth wall bunkers), an alternative to filling from the end is to dump the silage near the wall and push it into the bunker and forward to the leading edge. The silage mass itself with the help of a heavy tractor presses the air from the silage. The tractor must have wide tires to prevent getting stuck in deep silage. This method is most effective when large or several harvesters are working.



Figure 38. Filling of a horizontal silo starts at the end opposite the entrance with the pile sloping to the entrance

Only experienced operators should operate equipment on a horizontal silo or especially on a silo stack. Roll-over protection cabs should be used on packing tractors. Wheels should be set as far apart as possible and tractor speeds should be slow. The tractor should be weighted to have a low centre of gravity. Back onto silage piles and avoid stopping part way up a silage slope.

The temperature of the silage during ensiling is an indicator of the success of harvesting and silo filling. If the silage temperature exceeds 40°C (100°F), look at making the following adjustments:

- Harvest the crop at a higher moisture content.
- Reduce the length of cut so packing will be more effective. Note the sharpness of cutter bars can affect actual cutting length.
- Pack the silage more to exclude air.

Continue to monitor silage moisture and temperature to determine the correct wilting time and length of cut. Per cent moisture is best determined with a microwave oven or a moisture tester. Silage in storage should have a 60 to 70 per cent moisture content but 65 per cent moisture is the best level to aim for.

Covering horizontal silos

When the top surface has been properly packed, it should be covered immediately with six mil silage grade polyethylene or reinforced plastic to prevent fresh air or rainfall from entering the silage. Extend the cover forward often as the silo is filled. If there is an extended break in harvesting, the partially filled silo should be completely covered. The plastic cover must be held in place so air cannot enter the silage. A continuous layer of used tires works well for this purpose. If they are not continuous the plastic may blow in the wind and tear. They are easy to place as the plastic is spread out and easily removed as the silage is used. Straw bales or chopped silage may also be spread over the plastic. Another method is to use a fish net or twine mesh to hold the plastic tightly over

the silage. This stays tight after the silage shrinks and it requires little labor to handle.



Figure 39. A continuous layer of used tires works well to hold plastic covers in place

Seams and edges in the plastic cover must be sealed. A seal is made with an 18 inch overlap of the plastic sheets set into a groove in the silage surface. The seam is then covered with soil. Tears in the cover must be repaired to preserve the seal. The edges of a horizontal silo must be kept sealed since shrinkage leaves a space along the walls. Plastic covers last only one year. Covers not only prevent surface spoilage but prevent air from penetrating deep into the silage causing losses in the feed quality which are not obvious to the eye. As silage stacks and most bunkers have a large surface compared to the volume contained, covers are especially important to keep losses low. The spoiled silage on the surface of a 40 x 80 foot silo is estimated to be worth six times or more than the cost of a plastic cover.

Size and capacity of horizontal silos

The correct height and width to make a silo depends on daily silage usage based on the removal of a minimum of four inches (100 mm) per day from the silage face. Less usage leads to spoilage or freezing problems. It should be as high as possible to minimize the width, thereby minimizing spoilage from the surface. Height of silage also helps in packing the silage. The height is limited by the reach of unloading equipment, wall construction or to between six to eight feet if self feeding. A minimum width is 24 feet for front-end loader work.

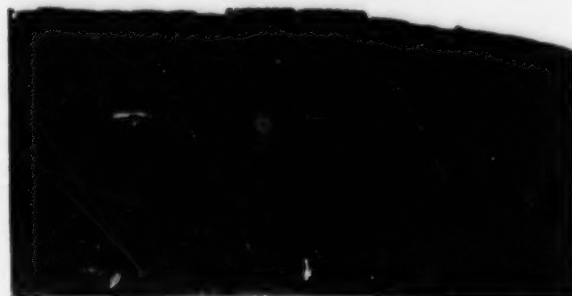


Figure 40. The greatest height which permits the removal of four inches per day from the silage face minimizes surface spoilage losses

TABLE 14. ESTIMATED CAPACITY OF HORIZONTAL SILOS CONTAINING 60-65% M.C. SILAGE*

Average silage density (lb/ft ³)	Silo width (feet)	Silage per 4 in. removal (tons)	Silo Capacity (tons)**			
			per foot	Silo length (feet)		
				60'	80'	100'
8	20	.85	2.56	125	173	221
32 lb/ft ³	24	1.02	3.07	150	207	265
(density ranges from 30 to 36 lb/ft ³)	30	1.28	3.84	187	259	331
12	24	1.73	5.18	249	353	456
36 lb/ft ³	36	2.59	7.78	373	529	684
(density ranges from 34 to 38 lb/ft ³)	48	3.46	10.37	498	705	912
	60	4.32	12.96	622	881	1140
16	36	3.84	11.52	507	737	968
40 lb/ft ³	48	5.12	15.36	676	983	1290
(density ranges from 37 to 42 lb/ft ³)	60	6.40	19.20	845	1229	1613

* Capacities are dependent on average densities of silage. Silage density increases with increasing moisture content, shorter cut length, packed silage depth and amount of packing.

** Capacity is calculated on the assumption that the far end of the silo is vertical and the front has a two to one slope i.e. twice as long as the height of silage in the silo.

Source - Silage storage, M.E. Bellman, Silage Seminar '76, Saskatoon, 1976.

The silo length depends on the total silage needed annually. Some horizontal silo capacities appear in table 14.

Silo capacities can only be estimated because the amount of packing, dry matter content of the material, length of chop and silage material will affect the storage capacity of silage/haylage in all types of storage structures.

Large round bale silage

Large round balers making "part sized" bales may be used to make packaged silage. Manufacturers' guidelines should be followed on the use of balers for silage since silage bales are much heavier than hay bales. The baler must be capable of making a dense uniformly packed silage bale of four feet (1.2 m) or less diameter to keep weights low enough for safe handling with most farm equipment. Forage can be baled for silage at 60-70 per cent moisture content. The best silage is made when the crop is cut young, wilted to the correct moisture content, then harvested quickly and sealed air tight as soon as possible but not longer than 12 hours after baling. It is important to make dense bales of a uniform size in making stacks to fit plastic bags well. The bales should be twine tied as for hay.

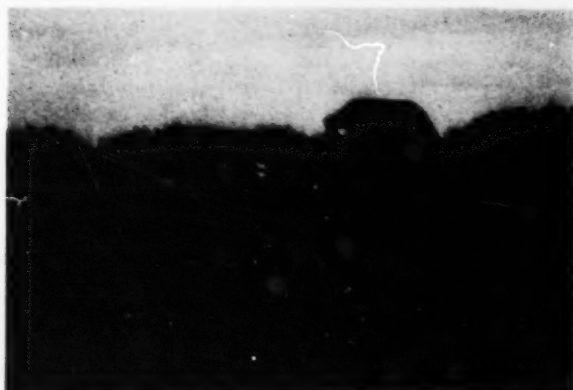


Figure 41. Bales of four feet diameter or less are required for safe handling of large round bale silage

Timing is critical with this harvest method. Heating and spoilage begin rapidly unless the ensiling process can be started. Baling when air temperatures are cool, such as in early morning, will slow the start of harmful heating.

The main advantages of round bale silage are low capital investment, low labor requirements and low fuel requirements for baling compared to chopping hay. Baling requires about one-quarter as much energy as chopping. It can be used as an alternative to hay baling in seasons when it's too wet to make hay. Crops that can be baled as hay and are reasonably easy to ensile such as most grasses, cereals or grass-legume mixtures, can be made into big bale silage. Disadvantages include a higher potential for spoilage and more critical timing of the operations.

Storage methods for large round bale silage

Trench silo: In this method big round bales are stacked as tightly and as evenly as possible into a trench. The bales are usually stacked three bales high. The trench should have a gravel or sand floor. Walls which slope outward make stacking easier. A packing tractor is used on the top to exclude air. Uniform placing of bales and careful use of a suitable tractor, such as a four wheel drive tractor with duals is required to do this.

The top is sealed with plastic similar to that used with chopped silage. It is advantageous to line the walls with plastic since bales do not form as tight a seal as cut silage.

Plastic bags: Individual bales can be placed in plastic bags. Bags are available in lengths to fit various bale chamber widths. A four foot (1.2 m) diameter size is common. Six mil plastic is recommended.

It is a demanding task to put bales into bags. They may be lifted with a front loader so the bag can be pulled on from the bottom. A single tooth prong on the front loader is forced into the centre of the bale to lift it and then the bag is slid on from the end.

Excluding oxygen is difficult since the bale contains air and the bag usually does not fit tightly. Piling the bagged bales before sealing the bag ends helps squeeze the air out. Both ends of the bag should be double tied to seal them after

piling. It is difficult to prevent tearing or puncturing bags during filling and piling. Holes must be patched.

Bales should be on a well-drained site. A sand floor is preferred. Outside stacks should be covered. Keeping the storage area free of vegetation, other stored feed, and baited for rodent control reduces the chance of rodents gnawing holes in the plastic bags.

Bagging machines have been developed to package up to 22 bales in 100 ft (30 m) plastic tubes. The process and management is similar to that for individual bags. This system requires a higher capital outlay. The tubes can only be used once.

Plastic-covered bale stacks: In this system large round bales are piled and covered with six mil polyethylene or reinforced plastic. A 40 x 100' (12 x 30 m) sheet of polyethylene without joints works well. Reinforced plastic makes a superior cover since it does not stretch or tear easily. Anchored fish net or twine is needed to keep the cover tight. The cover must be sealed around the perimeter of the stack. The main limiting factor with this system is that it is virtually impossible to adequately exclude air from the silage.

Tower silos

Tower or vertical silos are the most adaptable to mechanized feed handling. This silo type fits best where livestock herds are densely confined, but must be designed with the livestock feeding system in mind. They provide the silage system which is least affected by weather conditions. As initial construction costs are high, tower silos are most suitable where 2,000 tons (tonnes) capacity or less is required. Storage losses are generally lower and less variable than with other systems, and this may be an advantage when high quality feed is required such as for dairy herds.

Foundation footings for tower silos

The soil under the silo foundation and the foundation itself must be capable of supporting the silo and its contents. The footing must be designed for the size of silo, both diameter and height, and the type of soil on which it is placed. The footing must be designed to carry the weight of the silo wall itself and two-thirds of the weight of the stored silage. The height of a silo should be less than four times its diameter and the settled silage height only three to three and one-half times its diameter.

The soil must support the loaded silo without movement. A footing must have enough bottom surface area to distribute the silo and silage loads to the soil and still keep the soil pressure less than its maximum load-carrying capacity. Expect some variation in size and type of footings and a resulting variation in cost for different silos, depending on the soil type.

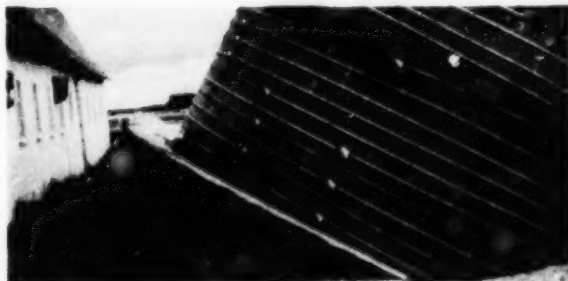


Figure 42. The soil under the silo foundation and the foundation itself must be capable of supporting the silo and its contents

Because the structural adequacy of a silo is so dependent on the construction of a proper footing, for the buyer's protection a silo contractor should be required to build and guarantee the footings. At the very least, the contractor should provide detailed plans and specifications for the construction of the footings based on the soil type, and should be prepared to accept responsibility for the whole silo, not just the part above the ground.

If in doubt, the purchaser should hire a soils consulting engineer to test the soil and design the footing. Lack of an adequate foundation and poor soil drainage have caused several tower silos to topple.

Pre-cast concrete stave silos

These silos have the potential advantage of excellent quality of construction at the manufacturing plant. They have relatively thin walls but the strength of the concrete is high. Pre-cast concrete stave silos can be erected quickly. The final quality of the silo is dependent on proper construction on the farm. An interior coating is needed to reduce the corrosive effect of silage acids.

Proper maintenance is very important. Adjustable steel hoops on the outside of the silo require the correct tensioning. These need to be re-adjusted after the silo has been used for one season. There is a potential for air leaks through the many joints between staves. These are filled with the interior coating in the silo.

Cast-in-place concrete silos

Cast-in-place concrete silos have relatively thick walls (compared to pre-cast types) and are structurally more suitable for large and especially for high silos. Critical strength is less affected by silage acid attack. There is less potential for air leaks, although construction joints may leak and should be sealed.

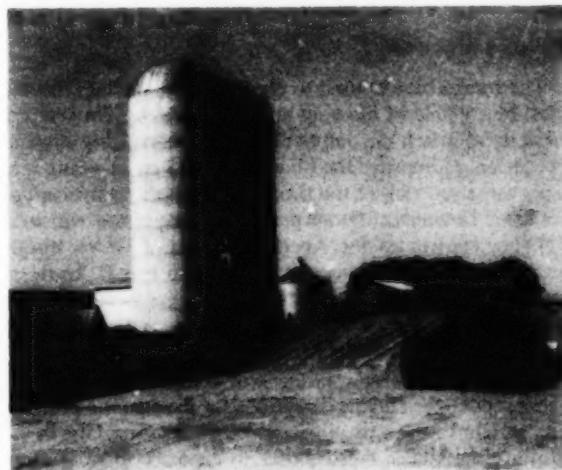


Figure 43. Cast in place concrete silo

Concrete tower silo preservation and repair

The corrosive action of silage acids on concrete and corrosion of metal fixtures is a major problem with all upright concrete silos. The greatest corrosion occurs on the bottom quarter of the silo especially the bottom 12 ft (3.7m). Corrosion is especially hazardous with tall silos since there is greater silage compaction causing increased seepage near the bottom. The need for high concrete strength is obvious. If

seepage is a concern after one filling cycle, lower moisture silage may be used during initial filling. Adequate moisture for good silage making still takes priority over seepage prevention.

High quality concrete is used in silo wall construction. It provides the necessary strength and a certain level of resistance to silage acid attack. Additives may be included in the concrete mix to improve the protection from acid corrosion of the silo wall. Acid resisting coatings may be applied to the silo wall interior to add more protection. Coatings must be applied according to the suppliers' directions. The use of concrete additives and wall coatings may be discussed with the silo contractor during the silo design phase.

Coatings may also be applied to existing silos provided the interior wall is adequately cleaned and prepared.

Oxygen limiting silos

These silos have airtight walls, floor and roof and an apparatus to stop entry of air into the silo. They provide maximum control of in-storage atmosphere but have a high initial cost. They operate well at a wide range of silo diameters. Oxygen limiting silos require periodic checking to ensure they remain airtight and that pressure relief valves and bags are operating correctly.

Moisture content of the silage should be 40 to 50 per cent. Oxygen limiting silos provide the highest potential for proper ensiling with minimum spoilage provided the silo has no air leaks. Bottom unloading permits continuous feeding with no sudden change in the ensilage while refilling the silo. Cost per ton (tonne) of silage stored depends on the number of times the silo is refilled each year. There is no minimum silage removal rate since the silo remains sealed.

Glass-lined steel silos have the potential for long life provided the seal is maintained between all component sheets. These silos may be extended in height if planned for at the time of initial construction. They may also be taken down and rebuilt at another location.

Filling a tower silo

The forage blower used to elevate the silage into the silo must be capable of blowing to the required height and at a capacity to match the output of the field harvesting system. Feeder boxes improve the blower capacity by allowing it to run a larger portion of the time. With proper adjustment of fan blade clearance, 25 tons per hour can be blown with a 55 PTO horsepower tractor. Another estimate of blower tractor power is one horsepower per foot of silo height. Uniform feeding to prevent overloading the blower helps avoid plugging. A small amount of water added at the blower helps keep legume crops or drier silage from sticking to the blower pipe.

Continuous loading and uniform distribution in the silo help produce the correct conditions for the ensiling process. The weight of the new silage added packs the silage in the silo. As the silo is filled closer to capacity there is more noticeable settling of the silage. More silage can usually be added after one or two days of settling.

To prevent seepage in silos over 80 feet tall, silage should be maintained at 65 per cent or lower moisture content. To reduce winter freezing problems keep the moisture content below 65 per cent in concrete tower silos and below 50 per cent in oxygen limiting silos.

Sizing and tower silo capacity

The diameter of a concrete tower silo is determined by the amount of feed needed to remove at least two to three inches

of silage daily. The larger the diameter of a silo, the lower the storage cost per ton. The height of the silo is determined by the amount of silage needed for the feeding period.

The maximum amount of silage to be stored at one time determines the size of an oxygen limiting silo since there is no minimum removal rate. The height to diameter ratio should not exceed four.



Figure 44. Oxygen limiting silo



Figure 45. Concrete stave silos

Silo capacities can only be estimated since moisture content, length of cut, crop used and friction of the silo wall all affect the density of the settled silage.

TABLE 15. SILAGE DENSITIES FOR VERTICAL SILOS

Density at 70 per cent moisture content, wet basis*

Average silage depth		Density	
m	ft	kg/m ³	lb/ft ³
3	10	550	34
10	33	685	43
12	39	745	47
14	46	795	50
16	52	845	53
18	59	890	56
20	66	940	59
22	72	980	61
24	79	1015	63
26	85	1055	66

*The moisture content of silage on the wet basis is the mass of water in the silage divided by the mass of the wet silage. The apparent density, D, in kg m⁻³ of silage at a moisture content other than 70 per cent is equal to

$$30 (D_{70}) / (100 - M)$$

Where D₍₇₀₎ = apparent density at 70 per cent wet basis

M = moisture content of silage/haylage wet basis

Example: 85 ft depth of silage at 45 per cent MC

Density = (30 x 1055) divided by (100 - 45) = 575 kg/m³
or (30 x 66) divided by (100 - 45) = 36 lb/ft³

Table 16 shows estimates of concrete epoxy coated and glass lined steel tower silo capacities for cereal, alfalfa and corn silage. Capacities for grass silage may be estimated from Table 16 by increasing the alfalfa silage capacity by 10 per cent for 50 per cent moisture, and by 15 per cent for 60 per cent moisture. The capacity of concrete tower silos without epoxy coated walls is less because of the increased friction between the wall of the silo and the silage.

Table 16. ESTIMATED EPOXY-COATED CONCRETE AND GLASS-LINED STEEL SILO CAPACITIES FOR FORAGES IN TONNES^a

Silo diameter x Settled depth		Cereal silage		Alfalfa silage			Corn silage		
(m)	(ft)	60%	70%	40% ^b	50%	60%	60%	65%	70%
3.7 x 9.1	12 x 30	50	71	34	43	56	52	60	70
3.7 x 12.2	12 x 40	69	100	49	61	80	74	84	99
3.7 x 15.2	12 x 50	89	129	63	79	105	96	110	128
4.3 x 12.2	14 x 40	100	141	68	85	112	102	117	137
4.3 x 15.2	14 x 50	127	183	89	112	148	134	152	177
4.3 x 16.8	14 x 55	142	204	100	125	166	149	170	197
4.9 x 15.2	16 x 50	172	248	120	150	198	177	202	234
4.9 x 18.3	16 x 60	213	307	150	188	248	220	249	287
4.9 x 19.8	16 x 65	233	336	166	207	274	241	273	314
5.5 x 15.2	18 x 50	224	322	155	195	256	227	258	299
5.5 x 18.3	18 x 60	278	400	195	245	322	281	318	367
5.5 x 21.3	18 x 70	333	479	236	296	389	336	379	435
6.1 x 18.3	20 x 60	353	506	247	308	405	351	396	456
6.1 x 21.3	20 x 70	423	607	300	374	490	419	471	540
6.1 x 24.4	20 x 80	496	709	354	441	576	487	547	625
7.3 x 18.3	24 x 60	531	756	368	459	600	512	577	662
7.3 x 21.3	24 x 70	640	908	449	558	727	611	686	784
7.3 x 24.4	24 x 80	751	1062	532	660	857	710	795	907
7.3 x 27.4	24 x 90	863	1217	616	764	988	809	905	1031
9.1 x 24.4	30 x 80	1232	1722	867	1070	1379	1269	1459	1606
9.1 x 27.4	30 x 90	1419	1975	1007	1240	1590	1472	1690	1950
9.1 x 30.5	30 x 100	1607	2229	1150	1411	1803	1678	1923	2116
9.1 x 33.5	30 x 110	1796	2483	1294	1584	2017	1886	2159	2374

^a 1 tonne = 1000 kg; the capacity in tons (2000 lb) can be obtained by multiplying the capacities in the table by 1.1.

^b Moisture content in per cent (wet basis).

Alfalfa and corn information adapted from Ontario Ministry of Agriculture and Food publication *Tower Silo Capacities*, Agdex 100/732.

Bagged Silage

Silage bags (continuous tubes)

Polyethylene bags (silo bags) provide low capital cost storage for silage. They can be used alone or as additional storage in combination with another system. Forage is chopped and compacted into a plastic tube with a bagging machine. A moisture content of 60 - 65 per cent is recommended although somewhat drier is also satisfactory.

Bagging machines exclude air in the process of stuffing forage into the bags. The silage bags are oxygen limiting systems although the plastic is not 100 per cent impermeable to

oxygen. Any tears or holes in the bags should be mended as soon as possible. Bags should only be used once. Silage bags are most satisfactory for short-term storage. After filling, silage should be used before the next summer. (For additional information see P.H. Robinson, J.J. Kennelly and G.W. Mathison, Influence of silo bag type on silage quality, 66th Annual Feeders Day Report, 1987, Agriculture and Forestry Bulletin, University of Alberta, p. 54-57.) Manufacturers' instructions for bagging machines and bags should be followed closely to achieve good results.

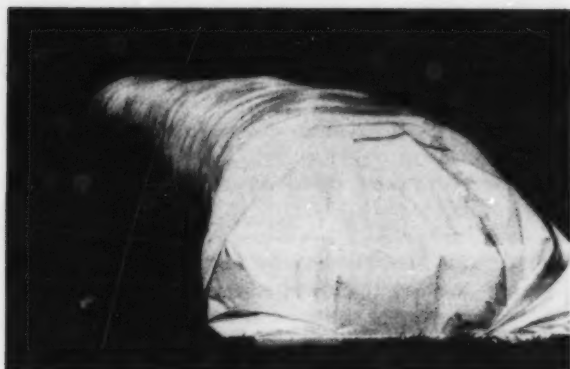


Figure 46. Silage bags (continuous tubes)

The most commonly used bag sizes are 8 ft (2.4 m) by 150 ft (45 m), and 9 ft (2.7 m) by 135 ft (41 m). However, bag sizes are available to fit various bagging machines and different quantities of silage. A standard 9 ft (2.7 m) by 123 ft (37 m) bag holds about 123 tons (111 tonnes) of 60 per cent moisture silage. This allows 6 ft (1.8 m) to seal each end of the plastic tube. The 9 ft (2.7 m) diameter bags contain about 1 ton/ft (3 tonne/m) of 60 per cent silage. An 8 ft (2.3 m) by 138 ft (42 m) bag holds about 110 ton (100 tonnes) or 0.8 ton/ft (2.4 tonne/m) assuming 60 per cent moisture silage.

Bag capacity and location

The bags should be located close to the feeding area since they cannot be moved once they are filled. The storage site should be well drained and level if possible. If they must be located on a slope the bags should be started at the top and proceed downslope. The storage area should be free of rocks or debris that could puncture bags. The area should be free of vegetation and other stored feed to discourage rodents from inhabiting the area and gnawing holes in the bags. Baiting for rodent control may be necessary. The area should be fenced from livestock and be sheltered from wind to minimize snow drifting problems.

Feeding silage

The choice of silo type is affected by the feeding system or method which is best for the farm. The type of feeding system is dependent on:

- degree of freedom of movement of the livestock herd
- the labor input to the feeding operation
- volume and timing of the feeding program
- type of livestock operation.

For example, most dairy confinement operators prefer a tower silo located close to the barn. This system is fully automated to convey silage directly from the silo to the feeder in the barn. The milking herd does not have to move from the confinement area. There is little waste in the mechanical conveyor system. The silo unloader must be checked regularly to ensure proper cutting adjustment, particularly in winter. The unloader may have to cut some frozen silage from the silo wall. Silage with a slightly lower moisture content will reduce downtime of silo unloaders.

In large feedlots silage is usually distributed to the feedbunks with a mixer feed truck or a feed wagon. Loading the silage from a trench or bunker silo is quickest with a front-end loader. The loader scrapes a slice from the silage face and loads the silage into a mixer feed truck or wagon. If a limited amount of silage is removed, a bunker silo unloader may be

used. This unloader has a cutting head that leaves a more cleanly shaven silage face to minimize spoilage. Operators that feed smaller groups of livestock have more flexibility, and a wider choice of silos can be used. With a reasonable amount of care and attention, losses of silage between the silo and the animal should be less than 4 per cent.



Figure 47. Front end loaders are quick for loading silage but care must be taken to scrape silage evenly from the silage face to minimize spoilage

With small livestock operations self feeding of silage is sometimes used to reduce machinery operating costs. For self feeding, cattle require a 10 in. (25 cm) width of feeding space per head. Maximum silo height is 8 feet (2.4 m). In winter at least 4 in. (10 cm) should be consumed from the face of the silo each day to minimize losses (6 in. or 15 cm in summer). Based on 50 head consuming 75 lb (34 kg) of 65 per cent moisture silage per day a 40 ft (12 m) wide silo, 8 feet (2.4 m) high would have 4 in. (10 cm) removed each day. However, summer use would reduce silo height by one-third to remove 6 in. (15 cm) of silage off the face.

Limit feeding in winter would reduce height by about half since more feeding space is required per head. The decreased height means there is greater surface area relative to silo capacity, i.e., surface spoilage losses are a greater percentage of the total. Self feeding often results in animals wasting feed. Other losses with self feeding relate to trampling. Systems based on self feeding should be used with an understanding of the limitations of this method of feeding.

Agricultural engineering staff can assist producers plan their silage systems from field to feedbunk. The overall system plan is very important to a successful silage operation.

Safety in silage making and storage

A well managed silage operation will normally avoid the circumstances which set the stage for an accident to occur. However, problems occasionally arise during harvesting, ensiling or feeding. To avoid accidents the motto must always be "safety first". Always take time to anticipate injury and life-threatening situations.

There are several situations which must be understood by machine operators. Silage cutters and blowers have parts which continue to rotate after the power-take off has stopped. Only when the tractor power is shut off and the machinery has stopped spinning can the operator check the sharpness of cutter knives or clear plugged material.

In horizontal silos the surface of silage being packed by a tractor is soft and unstable. The silage next to a bunker wall and the sides of silage stacks are particularly prone to giving

way under the tractor's weight. Steep slopes, or digging the drive wheels into silage can lead to backward overturn. The packing tractor should have a rollover protection cab and the operator should "buckle up".

Silo gas has claimed many lives. Always assume that both CO₂ (carbon dioxide), which can asphyxiate a human, and NO₂ (nitrogen dioxide) which is poisonous, are present in a tower silo. When nitrates are degraded in the ensiling process, nitrogen oxides are formed as products of microbial metabolism. The nitrogen dioxide (NO₂) which results when nitrogen monoxide contacts air is often called 'silo gas' and is highly toxic to man and animals when present in concentrations greater than 10 to 25 ppm. Pulmonary edema occurs when the gas combines with water in the lining of the respiratory tract and this can cause pneumonia-like symptoms and death. Even if the gas does not cause death, respiratory tract

damage can occur. Relapses are common after apparent recovery.

Since NO₂ is heavier than air, the brown gas is sometimes clearly visible inside silos or around silo openings. Most of the NO₂ is evolved from the silage in the first week of fermentation, with production peaking at two to three days after ensiling. There is essentially no NO₂ production after the material has been in the silo for more than 10 days.

In one survey 42 per cent of all silos tested contained NO₂ concentrations high enough to be considered hazardous to human health. Silo gas, therefore, must be expected in silos; precautions should always be taken, such as never entering an upright silo without running the blower for at least 10 minutes to circulate the air, and only with an approved breathing apparatus.

EVALUATING SILAGE QUALITY

Quality of the forage

Ensiling does not improve the quality of a forage. The quality of the feed that is taken out of the silo can be no better than the quality of the feed that was put into the silo.

Obtaining samples for quality examination

It is extremely important that a representative sample of silage be obtained for quality determinations. How useful the analysis of silage will be is determined in large measure by how well the sample taken represents the silage as a whole. It is of little value to do quality evaluation of a silage sample that does not represent the silage being fed.

Forage samples for analysis should be taken as the silo is being filled. Sample each field and crop type separately. Take small samples of each load brought to the silo. As soon as possible after a load is sampled the forage should be placed in an airtight container and in a cool place such as a refrigerator or freezer. Individual samples from one field or crop type should be well mixed and a subsample taken for analysis. Enough forage to fill a container the size of a bread bag is more than adequate for laboratory analyses. The container used should be sealed to avoid moisture loss and frozen until it is submitted or mailed to a laboratory.

Avoid shipping or mailing samples at times when mail delivery may be delayed, such as close to weekends or holidays, since fresh forage samples deteriorate rapidly under warm conditions. Send the forage samples to the laboratory near harvest time rather than waiting until just before feeding or until other samples are available. All laboratories receive very large increases in sample numbers in the fall and early winter; this may result in delays if you submit your samples during that time period.

If samples have not been taken at the time of harvest, take samples as the silage is being removed from the silo. Take care to get individual samples from as many sites as possible from the face of the exposed silage and then combine them into one sample for analysis. It is also important that these samples be taken as soon as possible after the surface of the silage is exposed. When sampling upright silos, combine individual samples taken over several days.

Visual evaluation of silage

By itself visual examination will not provide accurate

information on nutrient content of silage. However, coupled with a chemical analysis, factors such as color, odor and general appearance provide a good indication of the expected overall nutritive value. Characteristics which relate to nutritive value in grass and legume forages are listed in table 17.

The effect of the microbiological processes on the forage during ensiling needs to be evaluated, since even if the original material was of good quality the material may have ensiled poorly. Table 18 provides some guidelines for assessing this aspect of silage quality.

Chemical analyses of silages

Although silage quality can be estimated by visually examining the silage, it can only be estimated accurately by chemical analysis. The most important analyses obtained from feed testing laboratories include dry matter (moisture content is calculated as 100 minus percentage dry matter), pH, crude protein content, fibre, calcium and phosphorus. Analyses for other nutrients are also available.

Feed test reports can be evaluated in the same way for silages as they can for other forages. However, if the silage has heated too much, the digestibility of protein and dry matter may be greatly reduced. If heating (temperatures in excess of 40°C) has occurred, as evidenced by a charred appearance or tobacco-like odor, it is useful to have the laboratory perform an acid detergent insoluble nitrogen analysis (ADIN). In general, if the acid detergent insoluble nitrogen content of a material is above 0.3 per cent of the dry matter or 15 per cent of the total nitrogen in the forage, it is indicative that excessive heating has occurred.

Silage pH as an indicator of quality

The best single indicator of the effect of ensiling on the nutritive value of high moisture silage is pH. The relationship between pH and silage quality can be determined from table 19. In general the lower the pH the better, since it indicates that a lactic acid type of fermentation has occurred. pH is, however, not a good indicator of quality for silages which contain less than 65 per cent water.

Fermentation products in silage

Normally commercial laboratories do not determine the concentrations of acids or ammonia in silage. However, if this information is available it is very useful. In table 19 some characteristics of different qualities of silages are given.

TABLE 17. CHEMICAL AND VISUAL CHARACTERISTICS OF GRASSES AND LEGUMES IN RELATION TO FORAGE QUALITY

Quality	Stage of maturity	Protein (%)	ADF ² (%)	Description
Excellent	Prebloom legumes	19	under 31	40-50% leaves, less than 5% foreign material such as straw and weeds
Very Good	Early bloom legumes	17-19	under 34	35-45% leaves in legumes, more than 50% leaves in grasses, less than 5-10% foreign material.
Good	50% or more of legumes in bloom, boot to head stage in grasses	13-17	under 39	25-40% leaves in legumes, more than 40% leaves in grasses, less than 15% foreign material
Fair	Full bloom in legumes, grasses in head to milk stage	8-13	over 39	Less than 30% leaves in legumes, grasses 30-40% leaves, or more than 10-15% foreign material.
Poor	Legumes past full bloom, grasses in dough to seed stage	under 8	over 42	More than 20% foreign matter in legumes, very mature forage, few leaves, etc.

¹ Modified from Rohwedder, Barnes and Jorgensen, 1978 J. Animal Science 47:747.

² ADF - acid detergent fibre is a measure of the cellulose, lignin and cutin content of forages.

TABLE 18.

VISUAL AND pH EVALUATIONS OF SILAGE

Characteristic	Good quality	Intermediate quality	Poor quality	
			Poorly fermented	Overheated
SILAGE CHARACTERISTICS				
Color	Bright, light green-yellow or green brown depending upon material ensiled	Yellowish green to brown green	Very dark green, blue green, grey, or brown	Brown to black
Smell	Lactic acid ³ odor with no butyric ⁴ acid odor ⁴	Slight butyric acid and ammonia ⁵ odor	Strong butyric acid, ammonia, odor rancid	Burnt sugar or tobacco smell
Texture	Firm, with softer material not easily rubbed from fibre	Softer material can be separated from fibre	Slimy, soft tissues easily rubbed from fibre, moldy	Dry, easily broken down when rubbed, moldy
Moisture ¹	60-70% horizontal silos 60-65% concrete towers 40-50% oxygen limiting	Tends to be above 65%	Usually over 72%	Usually less than 55% Depends on type of structure
pH ²	Below 4.2 for wet crops, below 4.8 for wilted silages	4.6 to 5.2	Over 5.2	pH is not a reliable guide
CAUSES AND REMEDIES				
Cause	N/A	Too much moisture, not enough plant sugars	Too much moisture and insufficient plant sugars.	Too little moisture. Poor packing. Poor sealing. Length of cut too long, slow silo filling.
Remedy	N/A	Poor fermentation may be corrected by ensiling at a lower moisture, using preservatives or sealing silo	Wilt in field or use chemical and/or microbiological additives, seal silo quickly	Pack silage to exclude air, chop finer to facilitate packing, seal silage, ensile at a higher moisture. Fill silo rapidly and cover if delayed.

1 See Silage Harvesting Section for a method for estimating moisture content of silage.

2 pH can be determined with litmus paper which can be obtained from a pharmacist or use of pH meter.

3 Lactic acid odor is similar to that of sour milk.

4 Butyric acid odor is similar to that of rancid butter or fat, putrid.

5 Ammonia odor is similar to that in some household cleansers or anhydrous ammonia.

TABLE 19. FERMENTATION PRODUCTS IN DRY MATTER AND SILAGE QUALITY

Item	Silage Quality		
	Good	Intermediate	Poor
pH of silages with under 65% moisture	under 4.8	under 5.2	over 5.2
pH of silages with over 65% moisture	under 4.2	under 4.5	over 4.8
Lactic acid %	3-14	variable	variable
Butyric acid %	under 0.2	0.2-0.5	over 0.5
Proportion of total acids %			
Lactic	over 60	40-60	under 40
Acetic	under 25	25-40	over 40
Butyric	under 5	5-10	over 10
Ammonia N (% of total N)	under 10	10-16	over 16
ADIN (% of total N)	under 15	15-30	over 30

Good Quality Silage



Figure 48. Barley



Figure 51. Red clover



Figure 49. Alfalfa and timothy



Figure 52. Sweet-clover



Figure 50. Wheat and peas



Figure 53. Corn

FEEDING VALUE OF SILAGES

Nutrient content of hays and silages

Ensiling is an effective method of preserving feed with a minimum of nutrient loss. If ensiled properly the nutritive value is similar to that of the standing forage crop. Since fewer field losses occur when forage is ensiled than when it is put up as hay, material for ensiling often contains more nutrients than hay. However, there is a slight loss in quality during the ensiling process because plant sugars are degraded and proteins are broken down. The ultimate comparison between hay and silage will thus be influenced by the weathering and leaf losses which occurred during the haying process and the type of fermentation which existed during the ensiling process. In general, however, when rains are expected during the forage harvesting period, more nutrients are conserved with silage than with hay.

Chemically, fresh forage and silage differ greatly in two ways. Firstly, silage contains less water-soluble carbohydrates than fresh forage since these are utilized in the production of organic acids in the ensiling process. These organic acids do not have a large effect on the nutritional value of the material since they are produced in the rumen of the animal in varying amounts in any case. Secondly, considerable amounts of forage protein are degraded to nonprotein nitrogen compounds such as amino acids, amines and ammonia in the ensiling process. Protein degradation products in silage are not as nutritionally useful as intact proteins in most feeding circumstances, and amines in particular may cause adverse reactions and a lower feed intake in animals.

Generally, the digestible energy content of silage is quite similar to that of the forage from which it was made. Although the crude protein of silage is similar to the original forage, 10 per cent or more of the protein in the forage will have been degraded to nonprotein nitrogen. The mineral content of silages is as high as in the original forage unless measurable amounts of seepage have occurred. Silage made from green forage at the proper stage of maturity and without excessive heating in the silo can be a good source of vitamin A for animals. Since sunlight is necessary for the formation of vitamin D in forages after cutting, silage which has been left in the field for only a short period of time will contain little vitamin D.

Voluntary consumption of hays and silages

If growing or lactating animals are fed forage-based diets, the amount of forage which the animals will voluntarily consume is very important since this will determine the ultimate nutrient intake of the animal.

Once animals become accustomed to the taste of silage, they find it quite palatable, but for the first few days of the feeding period consumption can be quite low. Even when accustomed to silage, animals will generally eat less dry matter when silage is fed than when the same forage is fed in the fresh form. Also, ruminants will normally consume more dry matter when fed good hay than they will when fed silage of the same quality. With sheep the voluntary consumption of forage is decreased more through ensiling than with cattle.

Animals will eat more dry matter from drier silages than they will from wetter silages. The reasons for this are not completely clear, but it is known that the extra water in the silage is not the explanation. Decreased intake of high mois-

ture silage has been related to the various amines and ammonia produced when protein is degraded and to the formation of other organic compounds. Also, more total acids are produced with wetter silage and it has been shown that voluntary intakes can be increased if the acids in these silages are neutralized at the time of feeding.

Voluntary consumption of haylage and silage is increased by reducing the length of chop in the forage.



Figure 54. Livestock have greater daily intake from drier silages than they do from wetter silages

How much silage should be fed

Since silage usually contains more than 50 per cent water, animals have to consume more silage than hay to meet their nutrient requirements. In calculating amounts of silage to feed, the moisture content of the silage must be known so that the dry matter content of the material can be calculated. The dry matter content of silage will be essentially the same as the dry matter content of the forages put into the silo unless excessive seepage has occurred.

Table 20 shows the hay equivalents of silages with differing moisture contents. This can be used to estimate the amount of silage that should be fed.

TABLE 20. AMOUNT OF SILAGE REQUIRED TO PROVIDE THE EQUIVALENT OF 1 kg (lb) OF 90% DRY MATTER HAY

% Moisture in silage or haylage	% Dry matter	kg (or lb) of silage to replace 1 kg (or lb) of hay
40	60	1.5
45	55	1.6
50	50	1.8
55	45	2.0
60	40	2.25
65	35	2.6
70	30	3.0
75	25	3.6
80	20	4.5
85	15	6.0

It is also possible to calculate the amount of silage required by using the following procedures:

- (1) Calculate the dry matter content of silage as % DM = $100 - \% \text{ moisture}$
- (2) Calculate amount of silage to feed as:
 $\text{kg dry matter required} \times 100 \text{ divided by } \% \text{ dry matter in silage.}$

Example: If 11 kg of hay (91% dry matter) daily will meet the requirements of cows for the winter, it can be calculated that they will get 10 kg dry matter from the hay ($11 \times 91 \text{ divided by } 100$). If silage contained 60% moisture then it contains 40% dry matter (100-60). The amount of silage which must be fed can be calculated as $10 \times 100 \text{ divided by } 40 = 25 \text{ kg daily.}$

Feeding silage to different classes of livestock

Calves less than four months of age: Diet should not contain large amounts of silage. It tends to cause scouring and calves will not eat enough of it to meet their nutrient requirements. Some silage will not hurt them. As long as the animals are receiving enough milk, grain, protein, mineral and vitamin supplements to meet most of their nutritional requirements, silage can be fed as the only roughage source.

Growing calves from five months to ten months of age: Silage can be fed as the major constituent of the ration. There will, however, be a need for grain and other supplements to provide the animals with enough nutrients to gain at the minimum rate required for optimal productivity and economy. It is well to remember, though, that animals will normally eat less dry matter as silage than they will as hay, therefore, the amount of grain in the diet may have to be increased slightly when silage is fed. This is of particular importance when high moisture silage is fed.

Fattening cattle: Silage is a very good feedstuff to include in feedlot diets since it tends to reduce the incidence of bloat. For the first couple of days in the feedlot, hay is the preferred form of forage for cattle. Some of the animals may not be used to silage. Resulting low feed intakes can contribute to an increased incidence of sickness and poor performance at this time.

Replacement heifers over a year of age: These can be fed a silage based diet without grain supplementation provided the silage is of good quality.

Mature beef cows: Silage can be fed as the only source of energy and protein in winter. Only in extreme cases will protein supplementation be required. In all-forage diets, however, trace mineralized salt supplementation should be provided and phosphorus supplementation may be required. Vitamin D supplementation of silage diets is required in the winter. Vitamin A supplementation is recommended even though carotene levels may be high in the silage.

When good quality silage is available it may be advisable to limit the amount of silage fed daily and allow the cows to fill up on straw. This will result in a less costly ration and will prevent the cows from getting too fat. In cold weather, and as the time of calving gets closer, the amount of silage fed can be increased, and if necessary grain can be added to the diet.

Beef cows with calves: Silage made from high quality forage which contains less than 70 per cent moisture will usually be adequate without supplemental grain for beef cows nursing calves. If the silage contains more than 70 per cent moisture, or if it is of only average to poor quality, or if the level of milk production in the cows is high, supplemental grain or good quality hay will be required. If silage is being considered as the main feedstuff for nursing cows, it will be useful to have the forage tested since protein and other nutrient deficiencies are quite possible.

Breeding bulls: Feeding silage does not affect the quantity or quality of semen produced by bulls. Therefore silage can form the complete ration for bulls if mineral and vitamin supplementation are available. Supplemental protein will often be required when grass silages are fed. If the condition of a bull is poor, or the silage contains more than 70 per cent moisture, or the silage is of poor quality, supplemental good quality hay or grain should be considered.

Milking dairy cows: Silage is a good feed for milking cows if attention is paid to harvesting the forage at the proper stage of maturity.

Silage has been used successfully as the only forage source in the diet of milking cows. Diets based on silage as the only forage may contribute to low butterfat test. This appears to be caused by the short chop length common in silage which results in a reduction in the "effective fibre" content of the ration. In situations where this is a problem, various corrective measures can be taken including the addition of long or coarsely chopped hay in the ration. Increasing the length of cut may also be beneficial in higher moisture silages.

Problems can occur with off-flavored milk when cows are fed silage just prior to milking, especially grass silage that contains high levels of butyric acid. The off-flavor can appear if cows breathe the odor. Where this situation occurs, feeding the offending silage after milking may reduce or eliminate the problem.

Sheep: Some time is required for sheep to get used to the taste of silage, thus it should be introduced gradually into a diet over a two week period.

Silage can be fed to young growing lambs but grain, protein, mineral and vitamin supplements will be required to achieve acceptable growth rates.

Silage can provide the only roughage source for mature sheep once they get used to its taste. Some ewes, however, will not eat enough silage to meet their nutritional requirements. This is particularly true for ewes carrying twin lambs since rumen capacity is reduced because space in the abdominal cavity is taken up by the developing lambs. Silage of low nutrient content or excessively wet silage may not be consumed in sufficient quantity to meet nutrient requirements. Such silage should be supplemented with grain or good quality hay.

Horses: Silage is not usually thought of as a feed for horses but it can be fed as the only roughage source in the diet of mature horses. Care should be taken to make sure that the silage has not become moldy while in the silo or after it has been removed from the silo. Moldy feed should not be fed to horses at any time.

Special problems with feeding silage

Ketosis: There can be an increased incidence of ketosis in dairy cows fed silage as compared to cows fed hay. This problem is more likely to occur when poorly fermented silage with high levels of butyric acid is fed since butyric acid is metabolized to ketone bodies in the animal. There also may be problems with reduced intakes, which can cause ketosis, if lactating cows are switched from a hay to a silage diet too rapidly. Extra care should, therefore, be taken when lactating cows are switched to a silage-based diet, especially when they are not accustomed to silage.

Ketosis has also been reported to be a predisposing factor to pregnancy toxemia in pregnant ewes.

Nitrate poisoning: Nitrate-nitrite poisoning has been reported in animals fed silage. The amount of nitrate present in silage is always less than that which was present in the original crop. From 30 to 70 per cent or more of the nitrate in the original forage is degraded in the ensiling process. This, however, does not guarantee that nitrate toxicity will not occur when a high nitrate containing forage is conserved as silage. It appears that little degradation of nitrates occurs when the pH of the silage drops below 5. There is more degradation of nitrates in silage which has undergone an undesirable type of fermentation than in silage in which a desirable type of fermentation has taken place. Where nitrate poisoning could be a problem, it is advisable to test for

nitrate. Most feed testing laboratories do nitrate tests quickly and inexpensively.

Nitrogen dioxide poisoning: See the section on safety, page 34 for information on nitrogen dioxide poisoning.

Listeriosis: Listeriosis is a disease caused by the bacteria *Listeria monocytogenes*. The disease is commonly associated with silage but it can occur when silage is not being fed. It is also known as circling disease. Affected animals crowd into a corner, lean against fences and move in circles when walking. The disease affects the nervous system. Incoordination, high temperatures, lack of appetite, blindness, salivation and paralysis of jaw muscles also occur. The disease is usually fatal, especially with sheep, and those animals which survive have brain damage. Usually no more than 8-10 per cent of cattle are affected. The organism can also cause abortion in the third trimester of pregnancy.

Bacteria causing listeriosis are present on the vegetation and grow in the ensiling process only if the pH of the silage is above 4.2. The disease is more common in cold weather and when the animal undergoes stress. Nutrient deficiencies also may trigger the disease.

Listeria monocytogenes organisms also infect man so that precautions should be observed when handling an aborted fetus or in tasting silage to estimate quality.

Moldy silage is caused by fungi which grow readily on wet material when it is exposed to air. Under certain circumstances these organisms may produce mycotoxins which have adverse effects on animals. Moldy silage can cause severe diarrhea, loss of appetite, abortion, muscular tremors, pneumonia, changes in the lung, allergic reactions and death. Mycotoxins can also affect the microorganisms in the rumen.

However, in most instances small amounts of molds will not cause problems when fed to livestock.

Botulism: The microorganism *Clostridium botulinum* can grow in silage under conditions which favor clostridial organisms. Symptoms of this disease include paralysis of the throat, profuse salivation, lack of muscular coordination and often death. Cattle are less susceptible to botulism than horses since the toxin responsible for the problem is rapidly inactivated by ruminal microbes.

Dicoumarol poisoning: Sweet-clover contains varying amounts of coumarin. This chemical is often converted to dicoumarol in moldy feeds. Dicoumarol interferes with the blood clotting mechanism in animals and can result in excessive bleeding, anemia and death when fed to livestock. If sweet-clover silage is being made, care should be taken to avoid mold formation by carefully covering and sealing the silo. Also when feeding silage discard any moldy portions of the silage. It is often advisable to limit the amount of sweet-clover in the diet, particularly before the calving or lambing period. Low coumarin varieties of both yellow and white sweet-clover are now available but older varieties are high in coumarins.

Nutrient content of silages

The nutrient content of common forage crops grown in Alberta is given in tables 21 and 22. All values in these tables are on a moisture-free basis. The tables give the average level of the specified nutrient as well as the range of values one might expect in the various crops listed. As can be seen from the tables, the amount of any nutrient present in a feed is extremely variable. For this reason feed testing is recommended. Nutrient values for Saskatchewan silages are given in table 23.

TABLE 21. NUTRIENT ANALYSES OF SELECTED ALBERTA GROWN FORAGES CONSERVED AS SILAGE

	Number of samples		Moisture (%)	Protein (%)	Fibre (ADF) (%)	Calcium (%)	Phosphorus (%)
Alfalfa	308	Mean	55.4	18.2	36.1	1.77	0.25
		Range	30.3-86.7	10.6-25.7	21.9-51.6	1.02-2.86	0.15-0.40
Alfalfa-grass	465	Mean	56.8	14.6	37.8	1.32	0.23
		Range	30.3-79.2	6.8-23.3	24.7-54.3	0.28-2.67	0.12-0.38
Barley	699	Mean	63.2	11.1	32.8	0.46	0.26
		Range	37.8-87.6	4.3-18.8	8.5-48.5	0.08-1.06	0.12-0.43
Brome	6	Mean	57.3	10.5	37.1	0.53	0.20
		Range	46.0-67.5	8.8-12.0	26.3-46.7	0.33-0.80	0.14-0.28
Canola	13	Mean	65.3	13.9	42.3	1.23	0.31
		Range	30.2-83.3	8.1-20.5	26.5-55.2	0.69-2.06	0.21-0.48
Clover (unsp.)	141	Mean	63.5	14.7	42.6	1.39	0.21
		Range	33.4-88.0	10.7-20.6	27.6-57.9	1.00-1.90	0.11-0.35
Sweet-clover	16	Mean	64.4	16.1	39.7	1.30	0.22
		Range	45.0-81.5	7.8-20.5	28.1-63.0	1.04-1.71	0.01-0.33
Clover-grass	145	Mean	61.1	13.8	39.6	1.07	0.21
		Range	34.6-85.0	7.4-21.1	25.7-56.1	0.20-1.97	0.09-0.32
Corn	203	Mean	71.2	10.0	31.2	0.28	0.23
		Range	54.8-84.1	5.3-15.6	21.2-40.7	0.04-0.63	0.12-0.38
Fababeans	21	Mean	70.7	17.3	36.3	1.18	0.25
		Range	54.5-85.0	13.1-22.8	24.1-45.1	1.00-1.47	0.17-0.36
Grass (unsp.)	27	Mean	60.9	14.6	37.0	0.70	0.27
		Range	32.8-80.5	8.3-31.5	21.8-48.5	0.40-1.00	0.12-0.58
Legume-grass	660	Mean	58.2	14.3	38.2	1.23	0.23
		Range	30.3-85.0	6.8-22.6	24.7-56.1	0.20-2.66	0.09-0.38
Mixed cereal	93	Mean	62.1	11.0	35.8	0.48	0.26
		Range	37.2-79.8	6.3-18.3	23.0-52.2	0.15-1.21	0.13-0.45
Oats	201	Mean	62.1	10.6	36.3	0.39	0.24
		Range	33.8-86.0	4.4-18.8	26.1-57.1	0.07-1.01	0.10-0.38
Sunflower	6	Mean	74.5	12.2	33.8	1.29	0.21
		Range	63.0-84.7	11.0-13.9	28.7-42.8	1.01-1.59	0.17-0.27
Triticale	40	Mean	60.3	10.4	33.1	0.31	0.24
		Range	40.6-74.2	5.9-18.4	25.4-45.6	0.16-0.57	0.16-0.31
Wheat	29	Mean	57.0	11.2	37.8	0.25	0.24
		Range	32.1-76.6	6.5-18.5	28.6-50.7	0.11-0.49	0.16-0.39

Unsp = Unspecified

All values are on a moisture-free basis

Source: A.I.H. Suleiman, 1987 Average Analyses of Alberta Feeds
1976-1986, Alberta Agriculture, Agdex 100/81-6

TABLE 22.

**AVERAGE CONTENT OF MACRO AND MICRO MINERALS
IN SELECTED ALBERTA GROWN FORAGES CONSERVED AS SILAGE**

	Parts per million (ppm)							Per cent (%)				Parts per billion
	Cu	Mn	Zn	Al	Co	Fe	Mo	Mg	K	Na	S	Se
Alfalfa	7.0(81)	34.7(78)	26.5(78)	200(5)	1.23(3)	235(33)	1.83(14)	0.32(73)	1.81(66)	0.035(31)	0.27(6)	258(119)
Alfalfa-grass	6.5(97)	44.7(94)	24.8(97)	139(9)	0.56(1)	327(36)	1.77(21)	0.25(75)	1.74(74)	0.026(26)	0.18(14)	169(177)
Barley	4.8(91)	37.1(99)	32.5(90)	147(11)	0.52(8)	228(35)	1.35(32)	0.22(85)	1.50(82)	0.229(23)	0.20(21)	127(187)
Brome	3.5(1)	63.3(1)	19.0(1)	—	—	96(1)	—	0.17(1)	1.11(1)	0.002(1)	—	75(2)
Clover	6.9(21)	42.3(20)	27.0(21)	585(5)	0.31(1)	281(7)	1.20(7)	0.36(18)	1.63(18)	0.016(7)	0.11(3)	147(47)
Clover-grass	6.6(14)	61.0(14)	32.6(14)	65(1)	—	208(4)	1.12(1)	0.25(10)	1.48(10)	0.017(2)	0.11(3)	211(38)
Corn	5.4(21)	51.4(18)	52.9(20)	68(6)	0.36(5)	624(10)	0.76(7)	0.25(18)	1.43(17)	0.011(8)	0.08(6)	100(25)
Grass (unsp.)	7.05(5)	173.0(5)	26.5(5)	428(1)	—	418(3)	1.17(2)	0.25(7)	1.31(7)	0.143(2)	0.18(1)	162(11)
Kentucky bluegrass	5.2(8)	81.2(8)	29.0(8)	—	—	—	—	0.20(8)	2.13(8)	—	—	82(8)
Legume-grass	6.8(137)	47.0(132)	27.4(136)	171(13)	1.50(2)	323(42)	1.62(30)	0.25(113)	1.68(112)	0.048(31)	0.20(28)	116(251)
Mixed cereal	4.1(16)	47.3(15)	25.3(16)	—	—	—	1.28(2)	0.23(17)	1.59(14)	0.398(1)	0.19(4)	92(25)
Oats	4.4(30)	58.7(26)	29.5(29)	74(5)	0.37(4)	292(10)	0.91(6)	0.23(32)	1.72(26)	0.133(8)	0.16(7)	119(61)
Rye	2.9(4)	45.0(4)	26.5(4)	—	—	182(4)	—	0.23(4)	1.47(4)	0.006(2)	0.17(1)	90(5)
Sunflower	4.4(1)	—	—	—	—	—	—	—	—	—	—	—
Triticale	3.6(5)	36.0(5)	29.8(5)	—	—	211(1)	—	0.14(5)	1.64(5)	0.020(1)	—	69(5)
Wheat	6.0(1)	58.9(1)	40.7(1)	—	—	118(1)	1.15(1)	0.22(1)	1.26(1)	0.120(1)	—	113(3)

Unsp = unspecified

All values are on a moisture-free basis

Values in brackets refer to the numbers of samples analyzed

Cu = Copper Co = Cobalt K = Potassium
 Mn = Manganese Fe = Iron Na = Sodium
 Zn = Zinc Mo = Molybdenum S = Sulfur
 Al = Aluminum Mg = Magnesium Se = Selenium

Source: A.I.H. Suleiman, 1987 Average Analyses of Alberta Feeds 1976-1986, Alberta Agriculture, Agdex 100/81-6.

ppm = mg/kg. The concentration of microminerals in feeds is commonly reported in ppm (part per million) or mg/kg (milligrams per kilogram). Both terms are synonyms and are used interchangeably.

**TABLE 23. NUTRIENT COMPOSITION OF SOME
SASKATCHEWAN SILAGES (BASED ON
HAY EQUIVALENT BASIS 90% DRY
MATTER)**

Type of silage	Estimated Total Digestible Nutrients				
	Crude protein (%)	Fibre (ADF) (%)	(TDN) (%)	Calcium (%)	Phosphorus (%)
1) Cereal Silage					
Barley	10.5	32.0	58.0	0.35	0.23
Wheat	10.9	35.7	57.0	0.33	0.21
Oats	9.5	34.7	56.0	0.33	0.22
Corn	8.7	31.8	58.0	0.35	0.22
Rye	9.8	37.0	54.0	0.28	0.21
Sorghum					
Sudan Grass	12.0	33.8	55.0	0.45	0.21
2) Legume Silage					
Alfalfa	14.4	35.1	53.0	1.25	0.19
Sweet-clover	14.0	37.1	53.5	1.10	0.20
Alfalfa brome	13.4	37.2	53.0	0.87	0.20
Fababeans	16.5	—	58.0	—	—
Peas	15.4	35.7	58.0	—	—
Peas & oats	12.4	—	57.0	—	—

Saskatchewan Feed Testing Laboratory data

COSTS OF SILAGE PRODUCTION

Selecting a Forage System

Choosing a system for making silage becomes more complicated each year with the development of new machinery, storage and feeding components. Prudent farmers will be interested in designing a system that can do the job of forage harvesting, storing and feeding in a timely and effective way with the least cost per unit of feed used by the animals. Each producer must decide which system provides adequate efficiency of harvesting and storing with a low cost per ton of feed for his particular situation.

To compare different systems, farmers can estimate the capacities and requirements of each component in a well coordinated system and then estimate the annual revenue from additional income or decreased operating costs, and corresponding annual expenses (costs from additional capital investments and increased operating costs). The estimates of revenues and expenses for the project can then be reduced to an expected annual change in profits over the expected life of the system.

Estimating costs

Useful information for estimating current costs is published in *Farm Machinery Costs As A Guide To Custom Rates*, 1987, Alberta Agdex 825-4, *Custom Rates Survey Summary*, Alberta Agdex 825-9, and *Saskatchewan Farm Machinery Custom and Rental Rate Guide* available from the agriculture extension offices. Dealers, farmers, custom operators, etc. are also helpful in providing cost information.

In this chapter cost estimates for various systems have been prepared with information from the sources mentioned above, with fixed and variable costs per hour from *Farm Machinery Costs As A Guide To Custom Rates*, 1987, Agdex 825-4.

Production Assumptions

The assumptions for tables 26 and 27 are:

Two hundred and fifty acres of cereal silage are used to feed 200 head of beef cows at 20 lb dry matter (57 lb of silage at 65 per cent moisture) for a 200 day feeding period. The crop yields 2 tons of dry matter per acre (5.7 tons of silage at 65 per cent moisture).

- The crop is windrowed with a 16 foot self-propelled swather and wilted to 65 per cent moisture content for horizontal silos, concrete towers and silage bags, but 40 per cent to 55 per cent for the oxygen-limiting towers.
- Crop is chopped with a forage harvester that cuts 8.33 tons of dry matter per hour. Other equipment used includes a 120 HP tractor, a high dump wagon and a truck that holds 900 cubic feet of silage. Hauling distance is one mile.

Fixed costs

Fixed costs are estimated as annual costs of owning machinery and buildings. Fixed costs for the year are not direct costs but are allocated as a portion of the purchase price over the expected life of the asset.

Depreciation is an estimated annual charge of the loss in value of the asset because of diminishing years of remaining life, use and obsolescence. The formula for estimating it is:

$$\text{Depreciation} = \frac{\text{original cash cost} - \text{cash sale value}}{\text{years of use}}$$

Interest is estimated as an annual fixed cost by using the formula:

$$\text{Interest} = \frac{\text{original cash cost} + \text{cash sale value} \times \text{interest rate}}{2}$$

Insurance and housing is estimated at one per cent of the original cash cost.

Annual fixed costs for the blower and apron, and silage bag presser were calculated by the capital recovery method for 10 years at 10 per cent.

Blower and apron - Cost \$19000 divided by 6.1446 = \$3092

Silage bag (tube) silage presser - Cost \$45000 divided by 6.1446 = \$7323

It is assumed that the blower and apron for the tower silos is used only for 45 hours annually. The compressor machine for silage bags (tubes) is used for 45 hours on this silage job. The annual fixed cost of the bag silage presser is \$7323. The fixed cost would be about \$162 per hour (\$7323 divided by 45 = \$162.73).

It is assumed the forage harvester is used for 60 hours per year. If used for only 60 hours, the hourly fixed cost would be \$2520 divided by 60 = \$42.

The same assumptions are made for the swather, tractor, truck and high dump wagon that are being used for a total of 100, 400 and 300 hours respectively. The more hours the equipment is used, the lower the fixed costs per hour or per ton.

Annual fixed costs and the related hourly costs for a tractor, silage bag presser and a truck are shown in graphic form in figure 55.

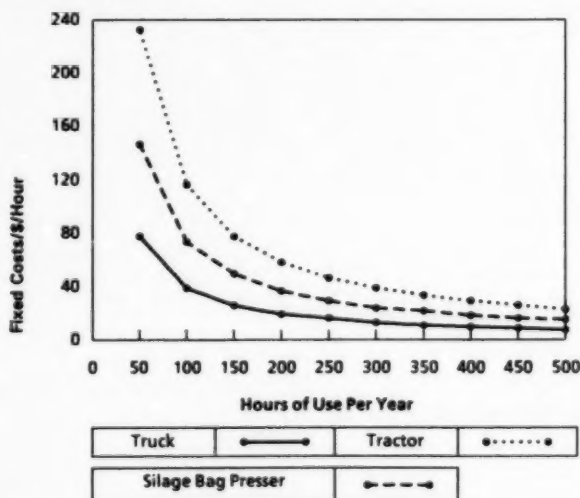


Figure 55. Hourly fixed costs based on annual hours of use

TABLE 24. ESTIMATED ANNUAL FIXED COST

Capital investment	Annual cost
\$73,000 - 180 HP tractor	\$11,600
\$26,000 - 3 ton truck	\$ 3,900
\$45,000 - 9 ft PTO silo press	\$ 7,323

TABLE 25. CALCULATIONS FOR FIGURE 55

Machine	Tractor	Truck	Silage Bag (tube) Silo Presser
Annual fixed cost	\$11,600	\$ 3,900	\$ 7,323
Hours used annually	\$ fixed cost per hour	\$ fixed cost per hour	\$ fixed cost per hour
50	232	78	146
100	116	39	73
150	77	26	49
200	58	19	37
250	46	16	29
300	39	13	24
350	33	11	21
400	29	10	18
450	26	9	16
500	23	8	15

Figure 55 illustrates the rapid decline in fixed costs per hour as the number of hours of annual use increases.

If all the silage equipment was used only about 50 hours per year to process 500 dry matter tons of silage, the fixed cost would be prohibitive.

For this reason, it is usually more economical to hire custom operators to make hay or silage in small quantities. The custom operators with many hours of annual machine use have lower fixed costs per hour and per ton.

Variable costs

Variable costs are all those costs not included in the estimated fixed costs. Variable costs increase as output increases and decrease as output decreases. Annual fixed costs, for comparison, do not change with output changes but stay fixed. Variable costs are cost of fuel, oil, repairs and so on.

Total costs

Total costs have been estimated for six different silage systems by estimating fixed and variable costs per hour for equipment times the number of hours used.

The estimated costs of swathing, cutting for silage, hauling to silo, packing and sealing for horizontal silos, blowing into towers and pressing into silage bags (tubes) are shown in table 26.

Present capital investment and annual capital cost for storage of silage are shown in table 27. The feed available after loss is not necessarily representative of individual silage producers' experiences. There is a great variation in the amount of feed that will be spoiled or wasted using different systems depending upon crop conditions and management practices.

To estimate the annual fixed cost of the storage structure, a capital cost factor of 8.51 is used to divide into the capital investment amount. This capital cost factor calculation represents the amount of money required at the end of each year to pay interest on the unrecovered capital at the designated rate and recover the investment within the specified number of years. The factor 8.51 is for 20 years at 10 per cent interest. This method is used in Appendix A of *Grass, Legume and Cereal Silages for Ruminants*, Agriculture Canada, publication 17861E. The number of years chosen to calculate capital recovery depends on the life of the asset and also the desired time for capital recovery by the investor. The interest rate chosen should be based on the weighted average cost of capital for the investor or what the investment could earn in an alternative use with the same risk.

Table 28 shows estimated variable and fixed costs for each system as well as the cost per dry ton fed after all losses are considered.

The cost per ton of dry matter fed varies from \$50 to \$84. The oxygen-limiting tower system has the highest fixed costs. The silage bag (tube) system has the highest variable cost because of the cost of the bags, which replace the fixed cost of storage in other systems.

Any system can be improved to lower costs. A change to using smaller equipment may lower costs if the variable cost increase is less than the fixed cost decrease, and if the longer harvesting and filling time required doesn't cause more feed losses elsewhere. Using older equipment will lower costs if the increased cost of repairs and down-time is not excessive.

Tower silos with higher capital investment costs, with only one filling each year in this example, are at a disadvantage by comparison. If the tower silos were in a system where they could be filled two or more times, their fixed costs per ton would drop considerably. These structures may be justified when savings in labor or increased feed value compensate for higher investment costs. However, for most farmers, the risk of investing this capital may be prohibitive.

Silage bag (tube) costs as shown in table 28 are high because of the high fixed cost of using the \$45,000 presser for only 45 hours at an annual fixed cost of \$7,335. Hiring a custom operator for \$3,200 per 200 ft tube holding 250 wet tons or more decreases the cost to \$55 per dry matter ton.

The tables show how to estimate costs, but the total cost figures are not meant to show which silage system is superior. Under different conditions or assumptions of costs and benefits, the results can be different from the results shown here.

TABLE 26.

**COSTS FOR 500 TONS DRY MATTER
(1429 TONS AT 65 PER CENT MOISTURE CONTENT)
OF CEREAL SILAGE**

Estimated cost from field to feeding
Fixed and variable costs

	Current replacement cost \$	Annual hours of use	Hours used for silage	Variable cost per hour \$	Total variable cost \$	Fixed cost per hour \$	Total fixed cost \$	Hours of labor	Total labor cost @ \$8/hr \$	Total cost \$
Swathing										
SP Swather-16'	28,000	100	35	11	385	41	1,435	40	320	2,140
Chopping & hauling										
PTO Forage										
Harvester	18,000	60	60	5	300	42	2,520			2,820
120 HP tractor	55,000	400	60	11	660	21	1,260	65	520	2,440
High dump wagon (900 cu ft)	11,000	60	60	2.20	132	23	1,380			1,512
3 ton truck hoist and box (900 cu ft)	26,000	300	60	13	780	13	780	60	480	2,040
TOTAL					1,872		5,940		1,000	8,812
Packing & sealing										
Horizontal silos										
100 HP tractor with blade	50,000	400	68	9	612	20	1,360	68	544	2,516
Plastic 60'x120'					200					200
TOTAL					812		1,360		544	2,716
Blowing into tower silos										
blower & apron	19,000	45	45	12	540	69	3,105			3,645
120 HP tractor	55,000	400	45	11	495	21	945	50	400	1,840
TOTAL					1,035		4,050		400	5,485
Compressing into plastic bags										
9' silage presser	45,000	45	45	30	1,350	163	7,335			8,685
120 HP tractor	55,000	400	45	11	495	21	945	50	400	1,840
Plastic bags 11 - 135' long x 9' @ 400					4,400					4,400
TOTAL					6,245		8,280		400	14,925
Feeding from trench silo to feed area with 100 HP tractor	50,000	400	100	9	900	20	2,000	200	1,600	4,500

TABLE 27.

ANNUAL STORAGE COSTS AND LOSSES FROM 500 TONS DRY MATTER IN THE FIELD BEFORE CUTTING

1429 tons wet at 65 per cent MC¹

	Present capital investment	Annual ² capital cost	Percentage & tons of crop available to be fed after total losses from field to feeding	
	\$	\$	% ³	Dry Matter
Trench (excavated)	6,250	734	75	375
Trench with floor & half wall	18,750	2,202	78	390
Bunker (above grade)	31,250	3,670	78	390
Concrete tower	75,000	8,809	83	415
Oxygen-limiting	150,000	17,618	84	420
Silage bags (tubes)	0	0	83	415

Assumptions¹500 tons of dry matter = 1429 tons of silage at 65 per cent moisture.²The annual capital cost is equal to the present capital investment calculated over 20 years at a 10 per cent discount rate. The capital investment factor is 8.51.³Estimated yields are based on the example in table 13.

TABLE 28.

TOTAL COST PER TON DRY MATTER FED BASIS 500 DRY MATTER TONS IN THE FIELD

	Swath \$		Chop haul \$		Silo filling \$		Feed \$		Total variable costs \$	Machinery total fixed cost \$	Storage structure annual fixed cost \$	Total cost \$	DM tons fed	Approx. total cost per ton DM fed \$
	VC	FC	VC	FC	VC	FC	VC	FC						
Trench silo (excavated only)	705	1435	2872	5940	1356	1360	2500	2000	7,433	10,735	734	18,902	375	50
Trench with concrete & half walls	705	1435	2872	5940	1356	1360	2500	2000	7,433	10,735	2,202	20,370	400	51
Bunker (above grade)	705	1435	2872	5940	1356	1360	2500	2000	7,433	10,735	3,670	21,838	400	55
Concrete tower	705	1435	2872	5940	1435	4050	500	(1)	5,512	11,425	8,809	25,746	405	64
Oxygen- limiting tower	705	1435	2872	5940	1435	4050	500	(1)	5,512	11,425	17,618	34,555	410	84
Silage bag (tube)	705	1435	2872	5940	6645	8280	2500	2000	12,722	17,655	n/a	30,377	410	74
Silage bag (tube) custom hire	705	1435					2500	2000	3,205	3,435		22,640*	410	55

VC = Variable costs which include labor costs

FC = Fixed costs

(1) Fixed costs included in annual fixed cost of storage

* Total cost includes \$6,640 in costs incurred directly by farmer and \$16,000 custom operator charge for chopping, hauling and packing of silage into bags.

Comparing two silage systems of different sizes

Tables 29 and 30 have been calculated to show estimated costs of two systems for filling horizontal silos. Each system has a different complement of equipment to ensile 1500 versus 3000 dry matter tons of cereal silage.

A horizontal silo should be filled in five days so silage can be packed and sealed efficiently.

TABLE 29.

COSTS FOR 1500 TONS DRY MATTER (4287 TONS AT 65% MOISTURE CONTENT) OF CEREAL SILAGE Estimated cost from field to storage Fixed and variable costs

	Current replacement cost \$	Annual hours of use	Hours used for silage	Variable cost per hour \$	Total variable cost \$	Fixed cost per hour \$	Total fixed cost \$	Hours of labor	Total labor cost @ \$8/hr \$	Total cost \$
Swathing										
SP Swather-16'	28,000	200	105	11	1,155	20.50	2,152	115	920	4,227
Chopping										
PTO Forage										
Harvester	24,000	120	120	7	840	28	3,360			4,200
180 HP tractor	73,000	400	120	14	1,680	29	3,480	132	1,056	6,216
Hauling										
Two 3 ton trucks	26,000	300	120	13	1,560	13	1,560	132	1,056	4,176
	26,000	300	120	13	1,560	13	1,560	132	1,056	4,176
Packing										
100 HP tractor and blade	50,000	400	130	9	1,170	20	2,600	140	1,120	4,890
Plastic for sealing silo					600					600
Annual fixed cost of storage ¹	48,000						5,638			5,638
Total					8,565		20,350		5,208	34,123 ²

¹ Cost based on two horizontal silos with concrete floors and half walls, 80 ft x 135 ft x 12 ft each

² Total cost per DM ton = \$22.75

TABLE 30.

COSTS FOR 3000 TONS DRY MATTER (8574 TONS AT 65 PER CENT MOISTURE CONTENT) OF CEREAL SILAGE Estimated cost from field to storage Fixed and variable costs

	Current replacement cost \$	Annual hours of use	Hours used for silage	Variable cost per hour \$	Total variable cost \$	Fixed cost per hour \$	Total fixed cost \$	Hours of labor	Total labor cost @ \$8/hr \$	Total cost \$
Swathing										
SP Swather-22'	33,000	150	150	11	1,650	27	4,050	165	1,320	7,020
Chopping										
PTO forage										
harvester-26"	37,000	150	150	7	1,050	34	5,100			6,150
275 HP tractor										
4 WD	117,000	400	150	16	2,400	40	6,000	165	1,320	9,720
Hauling										
Two 5 ton										
Tandem trucks										
Cost of each	38,000	300	150	12		16		165		
Cost for two	76,000	600	300	12	3,600	16	4,800	330	2,640	11,040
175 HP tractor										
4 WD for packing	72,000	400	150	10	1,500	25	3,750	165	1,320	6,570
6 mil plastic for sealing trench silo					1,200					1,200
Annual fixed cost of storage ¹	96,000						11,276			11,276
Total					11,400		34,976		6,600	52,976 ²

¹ Cost based on four horizontal silos with concrete floors and half walls, 80 ft x 135 ft x 12 ft

² Total costs per DM ton = \$17.66

Comparison of harvesting 500 tons of dry matter as silage vs round hay bales

Table 31A and 32A have been calculated to compare the cost of ensiling with the cost of hay baling.

These are the assumptions for baling hay:

- mower conditioner cuts 5 acres per hour for total of 50 hours
- baling rate is 12 bales per hour for total of 80 hours

- there are 960 bales of 1225 lb
- bales transported from field to storage at rate of 12 bales per hour for total of 80 hours
- tractor to load bales requires 40 hours of use to load and stack, and is also used for 50 hours operating the mower conditioner
- no bale storage costs are included.

TABLE 31A. COSTS FOR 500 TONS DRY MATTER (1429 TONS AT 65% MOISTURE CONTENT) OF CEREAL SILAGE

	Current replacement cost \$	Annual hours of use	Hours used for silage	Variable cost per hour \$	Total variable cost \$	Fixed cost per hour \$	Total fixed cost \$	Hours of labor	Total labor cost @ \$8/hr \$	Total cost \$
Swathing¹										
SP Swather-16'	28,000	100	35	11	385	41	1,435	40	320	2,140
Chopping & hauling¹										
Total					1872		5,940		1,000	8,812
Packing and sealing¹										
Total					812		1,360		544	2,716
Total cost from field to storage ¹					3069		8,735		1,864	13,668
Storage in trench silo ²							734			734
Feeding ¹					900		2,000		1,600	4,500
Total costs										18,902

¹ See table 26

² See table 27

TABLE 31B. TOTAL COST PER TON OF DRY MATTER AVAILABLE TO FEED:

% loss from field to feeding	Tons lost	Tons to be fed	Cost per ton fed
15	75	425	44
20	100	400	47
25	125	375	50
30	150	350	54

TABLE 32A.

**BIG ROUND BALE COST FOR SWATHING, BALING,
HAULING, STACKING AND FEEDING
500 TONS DRY MATTER HAY FROM 250 ACRES
(588 TONS AT 15 PER CENT MOISTURE CONTENT)**

	Current replacement cost \$	Annual hours of use	Hours used for hay making	Variable cost per hour \$	Total variable cost \$	Fixed cost per hour \$	Total fixed cost \$	Hours of labor	Total labor cost (@ \$8/hr \$)	Total cost \$
P.T.O. 12' mower conditioner	18,000	50	50	5	250	45	2,250			2,500
100 HP tractor to pull mower	50,000	400	50	9	450	20	1,000	50	400	1,850
Big round baler (1200 lb/bale)	19,000	80	80	6	480	33	2,640			3,120
80 HP tractor to pull baler	30,000	400	80	6	480	10	800	85	680	1,960
3 ton truck with hoist & 16' bed to haul bales	26,000	300	80	13	1,040	13	1,040	80	640	2,720
100 HP tractor load & stack bales	50,000	400	40	9	360	20	800	40	320	1,480
Total cost from field to storage area					3,060		8,530		2,040	13,630
Hauling from storage area to feed area 100 HP tractor	50,000	400	50	9	450	20	1,000	100	800	2,250
TOTAL COST					3,510		9,530		2,840	15,880

TABLE 32B.

TOTAL COST PER TON OF DRY MATTER AVAILABLE TO FEED:

% Loss from field to feeding	Tons lost	Tons to be fed	Cost per ton fed
20	100	400	40
25	125	375	42
30	150	350	45
35	175	325	49

NOTE: No hay storage costs have been included.

Comparing costs of silage-making by different systems and sizes

Table 33 shows the cost analysis of the three silage systems detailed in tables 26, 29 and 30; the round hay baling system in table 32 and the plastic tube custom hire system shown in table 28. The comparison between big bales and silage is difficult since bales are typically used for perennial forage while silage is typically used for cereals. The different equipment requirements are reflected in the example. The chopping of silage in the three systems was done with different sized forage harvesters and tractors.

	Dry Matter Tons		
	500	1500	3000
Forage harvester chopper width	20 in	26 in	26 in
Capacity in DM tons per hour	8	12	20
PTO HP of tractor	120	180	275

The total costs per dry matter ton for the 3,000 ton system and the 500 ton system are \$17.66 and \$31.74 respectively. This indicates that a custom operator with a large efficient system might be able to charge a lower rate per ton than it costs a farmer to do his own ensiling.

TABLE 33.

COMPARING COSTS OF SILAGE MAKING SYSTEMS AND BIG ROUND HAY BALES FROM FIELD TO STORAGE

Dry matter (Tons)	Cereal silage stored in horizontal silo with concrete floor and half walls			Silage bag (tube) custom hire	Big round hay bale (outside storage)
	500 ¹	1500 ²	3000 ³	500 ¹	500 ¹
Swathing cost	\$ 2,140	\$ 4,227	\$ 7,020	\$ 2,140	\$ 4,350
cost per acre	8.56	5.64	4.68	8.56	17.40
Chopping cost	5,260	10,416	15,870	-	5,080 ⁴
cost per DM ton	10.52	6.94	5.29	-	10.16
Hauling cost	3,552	8,352	11,040	-	-
cost per DM ton	7.10	5.57	3.68	-	-
Packing and sealing cost	2,716	5,490	7,770	16,000 ⁵	4,200 ⁶
cost per DM ton	5.43	3.66	2.59	-	8.40
Fixed cost of storage	2,202	5,638	11,276	-	-
cost per DM ton	4.40	3.76	3.76	-	-
Total Cost	15,870	34,123	52,976	18,140	13,630
Total cost per DM ton with no loss	31.74	22.75	17.66	36.28	27.26
Loss = 22% Loss = 17% Loss = 28%⁷					
DM TONS	390 tons	1,170 tons	2340 tons	415 tons	360 tons
Total cost per DM ton with estimated losses under good conditions	\$ 40.69	\$ 29.16	\$ 22.64	\$ 43.71	\$ 37.86
Capital investment for machinery and storage structures	\$206,750	\$275,000	\$431,000	-	\$143,000

¹ Costs based on 250 acres harvested.² Costs based on 750 acres harvested.³ Costs based on 1,500 acres harvested.⁴ Costs of baling.⁵ Custom hire for five 200 ft x 10 ft silage bags at \$3,200 per bag for chopping, hauling and filling. This includes cost of bags.⁶ Cost of loading, hauling, unloading and stacking big round bales.⁷ Leaf losses during baling represent the highest quality feed.

Benefits

It is more difficult to estimate benefits than costs when considering a change in forage harvesting systems. The benefits should be estimated on an annual basis to compare with costs. Benefits may include reduced costs, lower losses and higher quality of feed.

Investment analysis

After expected benefits and costs are projected, it is possible to analyze the investment alternatives. Partial budgets,

payback analysis, net present value analysis or other methods can be used. Farmers should try to determine what the best alternative investments are and then calculate how to finance the best investment. Factors to consider are inflation, risk, time, value of money and income tax. Projected cash flows should be prepared if financing is needed. Farmers can contact their district extension staff, regional economists or farm business management branch for assistance.

APPENDIX 1

REFERENCES

General:

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